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U-Pb GEOCHRONOLOGY OF URANIUM MINERALIZATION IN THE EAST ARM OF GREAT SLAVE LAKE, N.W.T.

BY

© GRAEME R. BLOY

A THESIS

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DEPARTMENT OF GEOLOGY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled U-Pb GEOCHRONOLOGY OF URANIUM MINERALIZATION IN THE EAST ARM OF GREAT SLAVE LAKE, N.W.T., submitted by GRAEME R. BLOY in partial fulfilment of the requirements for the degree of Master of Science in Geology.

ABSTRACT

U-Pb apparent ages of seven uranium mineral occurrences in the East Arm of Great Slave Lake, hosted by the Great Slave Supergroup, range from 1510 m.y. to 1755 m.y.. These ages were obtained from concordia intersections of moderately to highly discordant samples. Radiogenic Pb loss is the major cause of the discordant values. Polished-section studies often show galena formed from radiogenic lead derived from the parent uranium mineral and this is confirmed by the lead isotope systematics of the samples. Bulk leach and handpicked samples both show lead discordance to the same degree; indicating that radiogenic lead has migrated at least tens of centimeters away from the uranium mineralization.

The analyzed mineralization is located at various points within the Great Slave Supergroup sedimentary-volcanic "wedge" such that a maximum and minimum age could be obtained for this stratigraphic unit. However only the apparent U-Pb age of 1755 m.y. confirms the published Rb-Sr minimum age of the Great Slave Supergroup. Two other dates of 1510 m.y. and 1671 m.y. represent updates or dates of epigenetic mineralization much younger than their host rocks.

Petrographic-, polished section- and trace element geochemical- studies suggest that a variety of types of uranium deposits exist in the Great Slave Supergroup. Trace element associations are different for each deposit (no source correlation), while the mode of emplacement is also different for most of the deposits as determined from petrographic and ore microscopic studies.

ACKNOWLEDGEMENTS

The author would like to thank Vestor Exploration Ltd. and Reg Olsen of Trigg, Woolett and Associates Ltd. for supplying the ore samples analyzed in this study. I would like to thank my friends for their help and advice, particularly Chris Van Dyke, Chris Held and Bob McPherson. I had a number of fruitful discussions with Drs. Baadsgaard, Cumming and Morton and Steve Goff which crystallized concepts on isotopes and geology in the East Arm. I would like to thank my parents (both sets) for their encouragement and support over the years. Finally, I would like to thank my wife, Raymonde, for prodding me to complete this work.

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INTRODUCTION

Minerals from seven uranium deposits present in the Great Slave supergroup and the Union Island group have been evaluated for their U/Pb systematics, trace element geochemistry and mineralogy. The study sought to obtain viable geochronologic data by observing and experimentally determining the variables in the subject deposits. Stieff et al (1963) state that "the most reasonable age can be selected after careful consideration of independant geochronologic as well as field, stratigraphic and paleontologic evidence, and the petrographic and paragenetic relations". This study entails this concept where trace element geochemistry, sedimentology, petrographic and paragenetic relations of the ore plus field relations were used in conjunction with the Pb/U age determination to obtain the most reasonable age of the uranium deposits in the East Arm.

With the data obtained by the author and other workers, it was possible to determine what type of uranium deposit was investigated, whether it was hydrothermal, precipitated at low temperatures or deposited in an ancient stream.

Thus, the object of this study is to determine the age relations of the uranium deposits with respect to the Great Slave Supergroup and investigate the nature of uranium deposits present in the East Arm of Great Slave Lake.

I. GEOLOGICAL SETTING

A. LOCATION

The uranium deposits investigated in this study are located in the east arm of Great Slave Lake in the Northwest Territories of Canada between latitudes 61° 30'N and 63°N and longitudes 109°N and 113° 30'W. The location of each deposit is shown on Figure 1. These deposits are present on the Simpson Island (T), Union Island (45), the Labelle Peninsula (71), Toopon Lake (TL), Stark Lake (11 and 28) and Meridian Lake (P and Rel.).

B. REGIONAL SETTING

The uranium deposits are located in the Great Slave Supergroup and the Union Island group (Figure 2). These stratigraphic units form a sedimentary-volcanic pile which has undergone an extensive tectonic and magmatic history. The regional stratigraphy of these sediments and volcanics has been mapped and described by Hoffman (1978, 1970, 1969, 1968) while the regional structure has been mapped in part by Reinhardt (1969). A synthesis of the regional stratigraphic and structural geology has been prepared by Hoffman (1977, 1974, 1973). The regional stratigraphy and structural relationships are present in Figures 2 and 3 respectively.

C. LOCAL SETTING

1. Simpson Island Deposits (T)

These deposits are located at the western end of the East Arm (Figures 1 and 4) and were discovered by Vestor Exploration Ltd. Walker (1977)

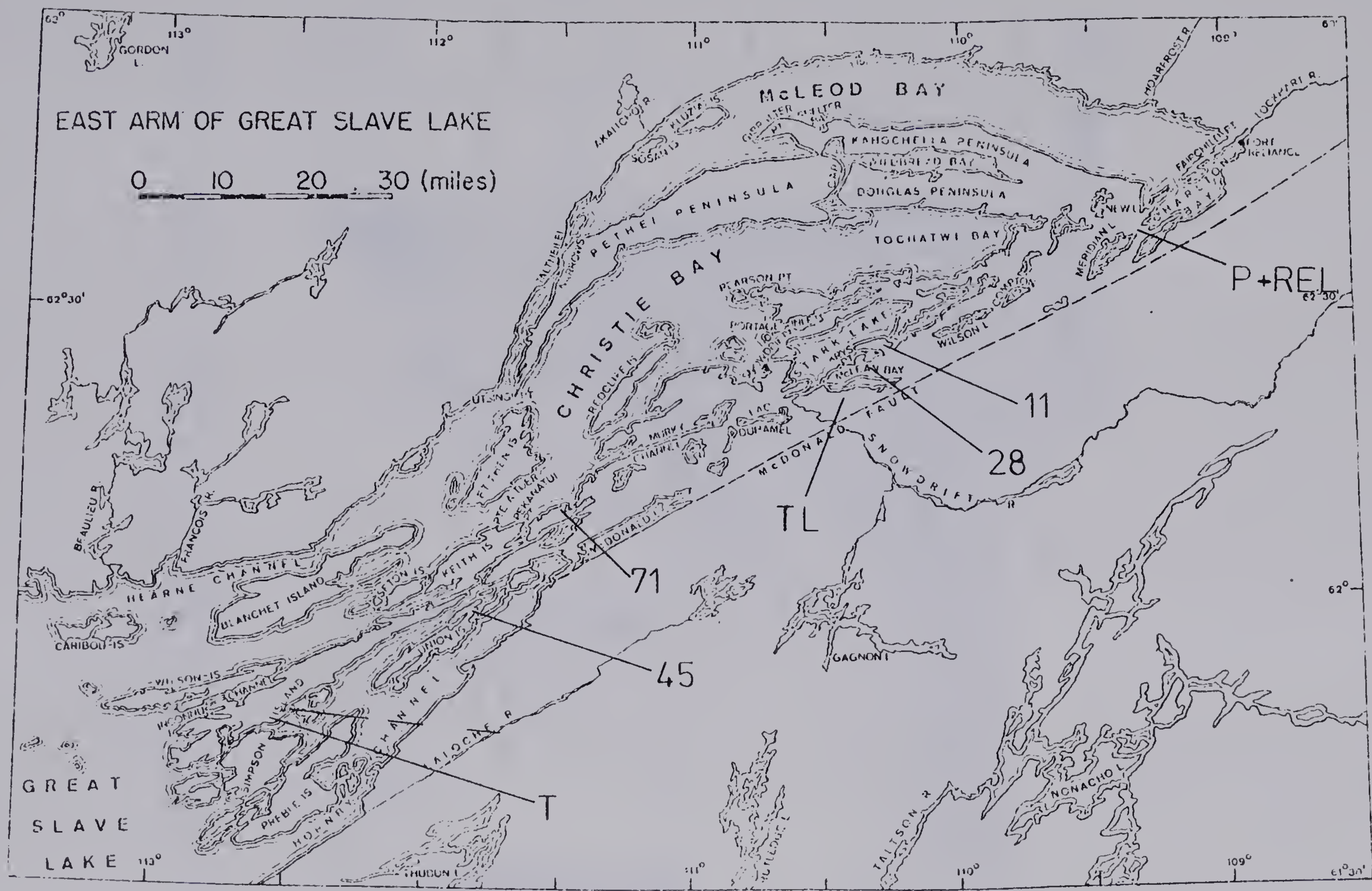


Figure 1. Location of Map of Investigated Uranium Deposits. (Hoffman, 1968)

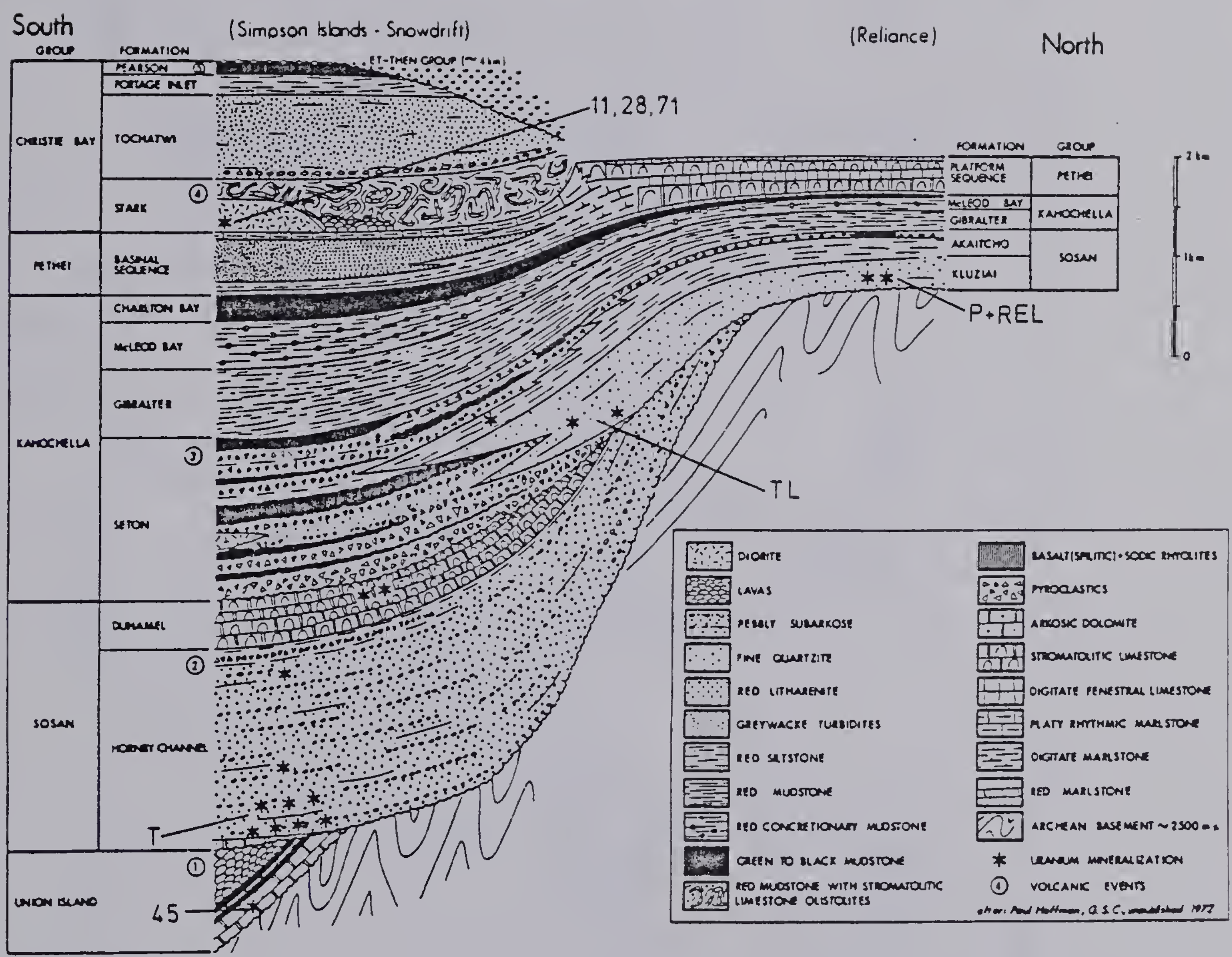


Figure 2. Diagram of Regional Stratigraphy in the East Arm with the Position of the Subject Deposits. (Morton, 1974)

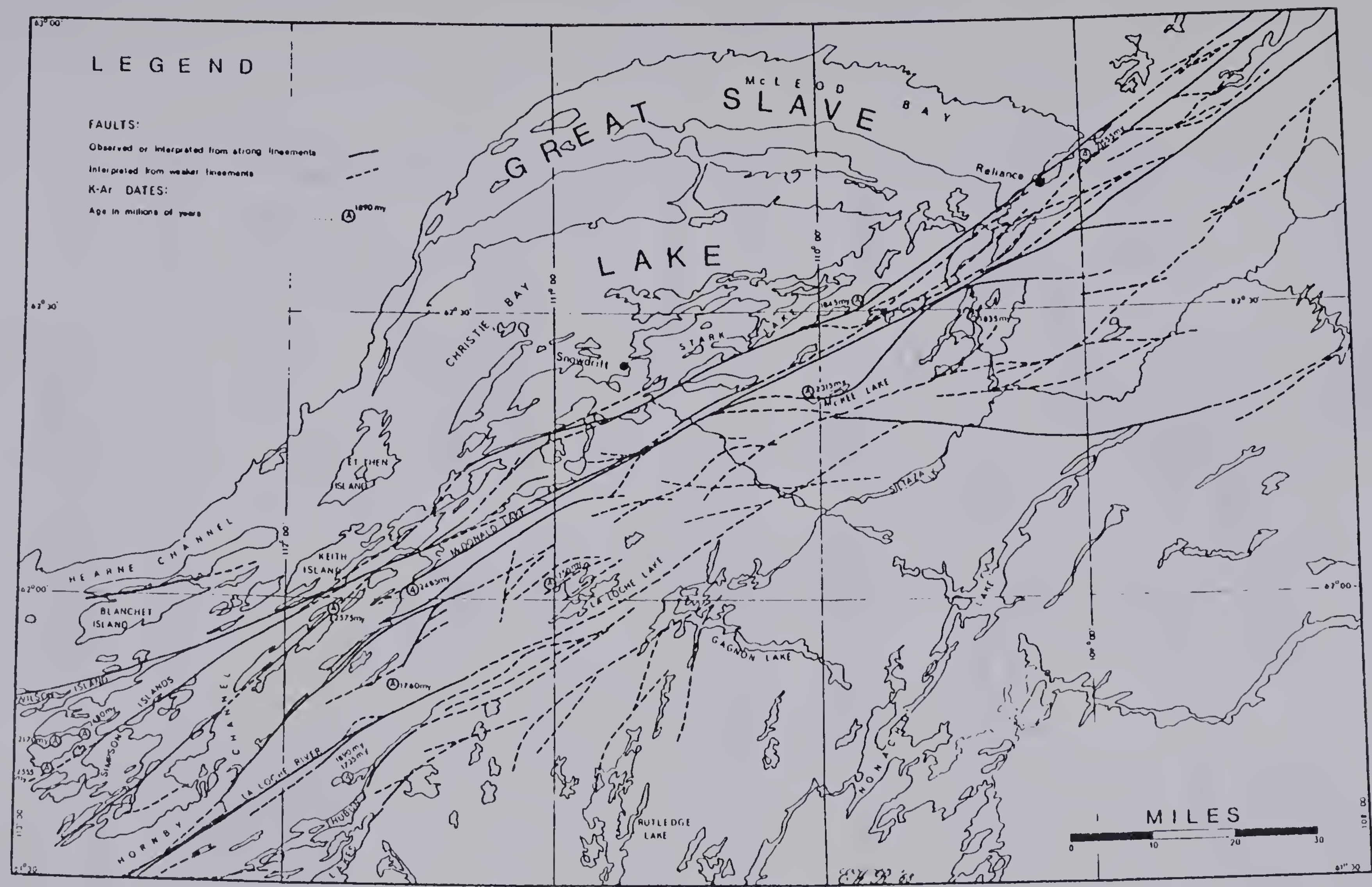


Figure 3. Regional Structure of the East Arm of Great Slave Lake. (Reinhardt, 1972).

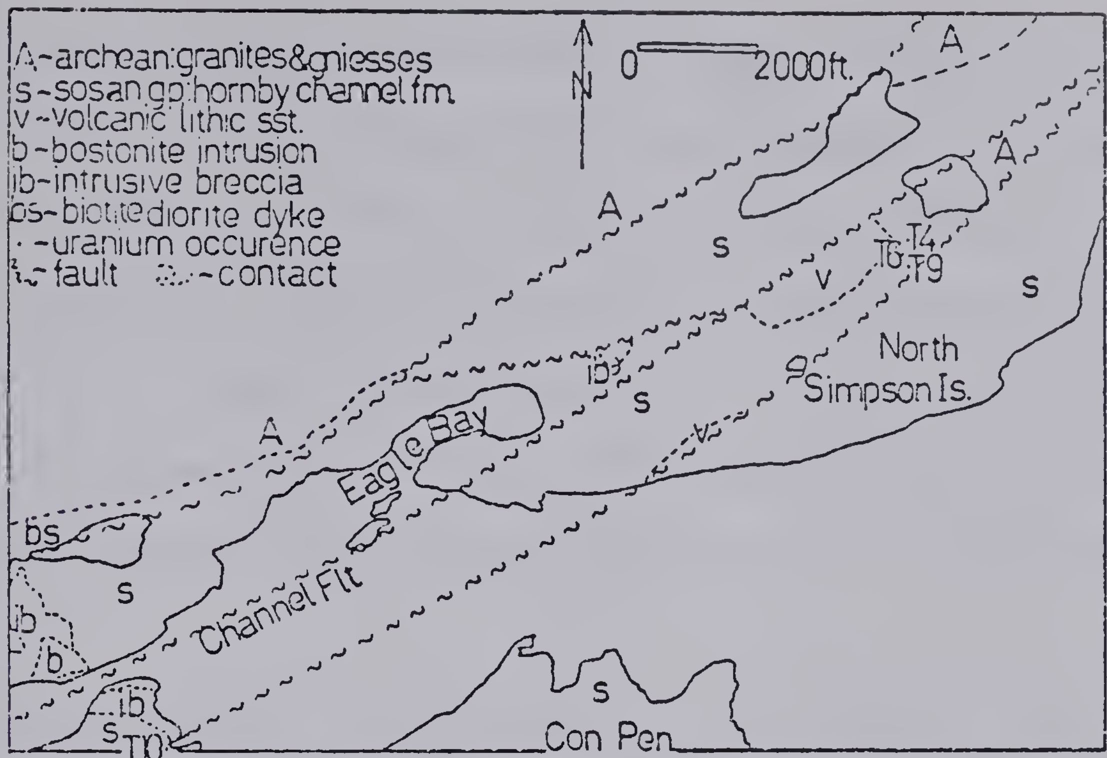


Figure 4. The Local Geology of the Simpson Islands Deposit. (Walker, 1971)

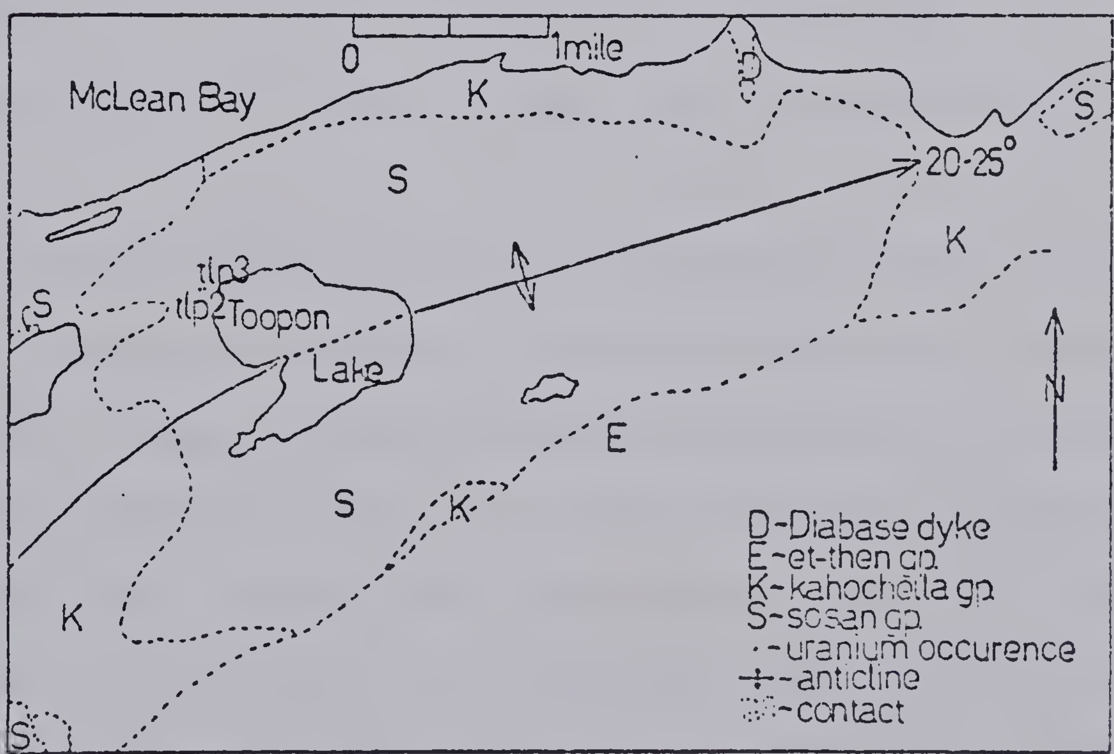


Figure 5. The Local Geology of the Toopon Lake Deposit. (Oladegdule, 1971)

describes in detail these occurrences, which are located in the Hornby Channel Formation. This host unit is situated between the Simpson and Preble fault systems as a wedge of clastics dipping 10° to 15° to the northwest (Figure 4). Close to the faults on the northwest and southwest sides of this wedge, the bedding of the clastics becomes parallel in strike with these faults. Walker (1977) and Hoffman (1977) suggest that these faults were active during the deposition of the Hornby Channel Formation.

The Hornby Channel Formation present on the Simpson Islands is greater than 1500 metres thick. The uranium mineralization occurs in a silicified, sericitic, conglomeratic sandstone unit of this Formation. Thin section and hand specimen examination suggests that the host unit is a subfeldspathic slightly conglomeratic granule-stone. This unit is white to buff in colour, poorly sorted, tightly cemented and well silicified.

Grain size and hematite laminae define bedding and cross bedding and show numerous scour surfaces together with some rare graded beds with basal scours. Large, tectonically-squeezed lenses of pale green, microcrystalline sericite and areas with larger amounts of sericite matrix are present within the host unit. These lenses vary in size from two centimetres to three metres thick and appear to be seldom parallel to bedding. The sediment of this host unit is derived from a braided-stream fluvial system. The sericite lenses and units with more sericite represent vertical accretion deposits and the granule-stone represents the channel and bar deposits (Walker, R. G., 1976). This lithologic unit is approximately 275m thick, and therefore most of the uranium mineralization occurs less than 300m above the basement unconformity (Figure 2).

To the west along the Simpson fault system (ie., the Channel flt.) there has been intrusion of a biotite diorite dyke. Bostonite intrusions and diatreme activity (Figure 4) plus widespread albitization and silicification of the host unit occur near the fault system. The timing of these intrusions is not known, but the diatremes and bostonite intrusions appear to be contemporaneous, while the biotite diorite is apparently unrelated to the other intrusions (Walker, 1977).

Walker (1977) states that the Hornby Channel Formation has undergone a very low grade of burial metamorphism of the pumpellyite-prehnite-quartz facies. This mineral assemblage occurs near the uranium mineralization in an unusual unit of sandstone rich in volcanic debris (Figure 4). This volcanic debris is altered to spherulitic aggregates of chlorite plus sericite, carbonate, prehnite, pumpellyite and albite.

Uranium mineralization in the host Hornby Channel Formation occurs as two types, a "reduced" type, which is highly radioactive and composed of uraninite and pyrite (this type was analyzed) and an "oxidized" type, low in radioactivity and containing hematite (Morton, 1974). The mineralization is similar to the Huronian uraniferous conglomerates of the Elliot Lakes and Blind River area where Roscoe (1968) notes "there are two types of conglomerates, one contains abundant iron oxides such as hematite; the other, pyrite." High radioactivity is associated with the pyrite-bearing unit as in the Simpson Island occurrences. The reduced mineralization of the Simpson Island occurrences cuts across the bedding, indicating remobilization.

These occurrences have undergone tectonic and metamorphic events which have undoubtably affected the chemical and isotopic equilibrium of the deposits.

2. Toopon Lake (TLP, TLX)

The Toopon Lake occurrences were discovered by Vestor Exploration Ltd. and are described by Olade (1972 and 1971) The are located by Toopon Lake south of Maclean Bay (Figures 1 and 5). All the occurrences are endemic to a sandstone of the middle member of the Kluziai Formation. The structurally competent Kluziai Formation is folded into a large anticlinorium plunging to the northeast. Faulting within this area is minimal.

The mineralization (T.L. pits 2 and 3) occurs to the west of the lake (Figure 5) and forms a radiometric anomaly trending N.E. - S.W.. The host orthoquartzite is well-sorted, well-rounded, fine-grained, indurated, and silica-cemented. The bodies of uranium mineralization are lensoidal or ellipsiodal in nature with cores of black to dark grey sandstone with an envelope of hematite which in turn is enveloped by limonite and secondary uranium staining. The primary mineralization is interstitial and stratabound within the host, and is not fracture controlled. Secondary uranium mineralization appears on northwest trending fractures and joints and is usually associated with hematite. It appears the mineralization is surficially weathered with only cores of reduced mineralization remaining.

3. Rex Claims (11)

These claims have been described by Lang (1962), McGlynn (1971) and Badham (1977). They are located on the north shore of Regina Bay on the south edge of Stark Lake (Figures 1 and 6). This uranium mineralization is hosted by one of the quartz monzonite laccoliths of the Caribou intrusions, which intrude the Stark formation. There are six zones of

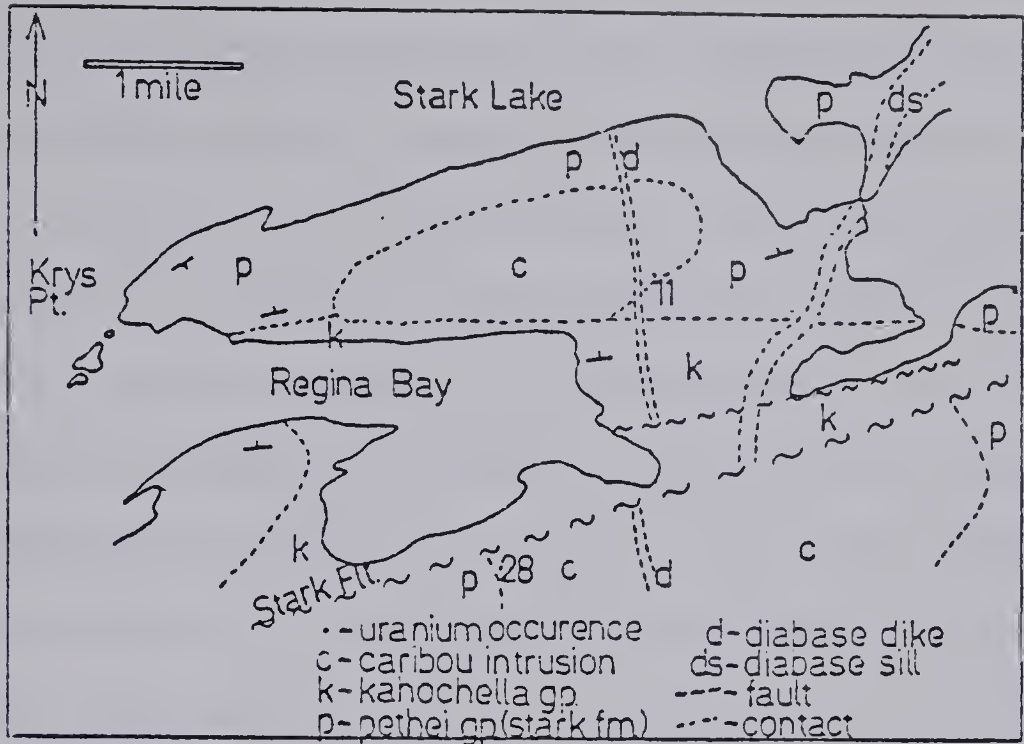


Figure 6

The Local Geology of the Rex (11) and Fair (28) Deposits. (Badham, 1977)

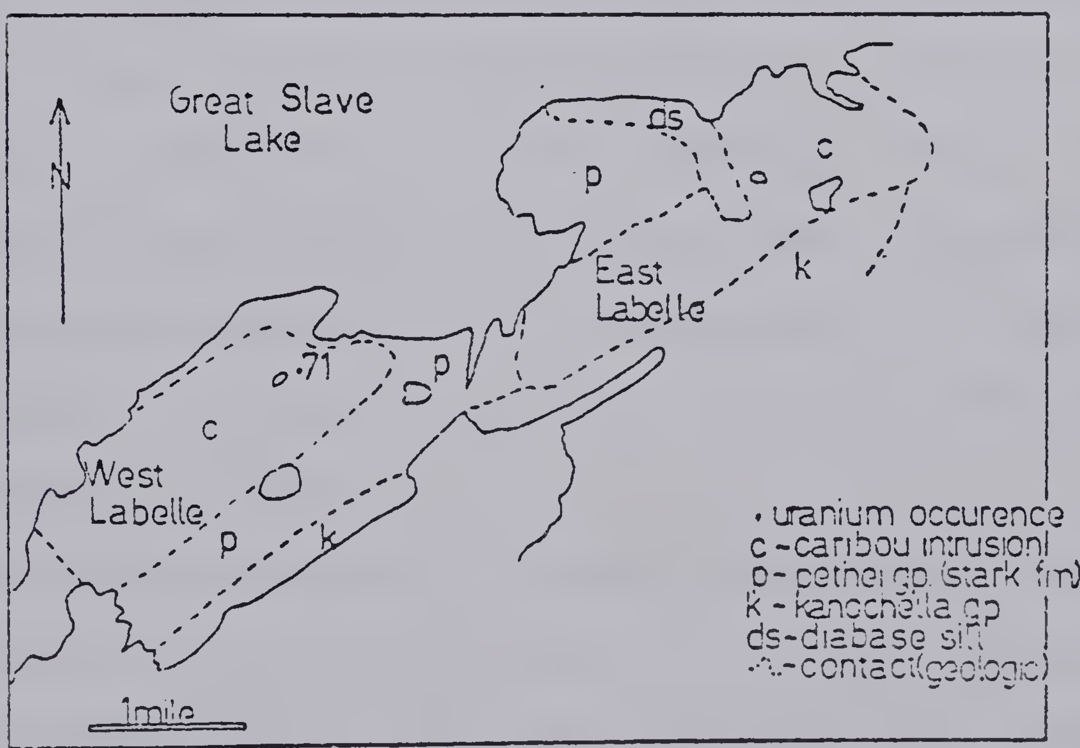


Figure 7

The Local Geology of the C. C. Deposit. (Badham, 1977)

radioactivity. The zone sampled was the "C" zone which is the richest, and is a northwest-trending, vertically-dipping vein 190m in length, 40 to 125cm in width and up to 140m in depth. The vein pinches out with depth and length. This vein is coarse-grained in texture, and composed of actinolite, magnetite, apatite with minor amounts of K-feldspar, quartz, uraninite, pyrite, chalcopyrite, calcite and fluorite. The habit of the actinolite is acicular and these cyrstals are orientated perpendicular to the vein walls. Magnetite and uraninite are closely associated, with radioactivity being greatest in the magnetite-ricn portion of the vein material. The average grade (much quoted) for U_3O_8 is 0.29% over a 1.2m sample width.

4. The Fair Claims (28)

The Fair Claims are located on the south shore of Regina Bay on Stark Lake (Figures 1 and 6). This mineralization is located within a quartz monzonite laccolith (the Caribou intrusives) which is underlain by red mudstones and dolomites of the Pethei group. The quartz monzonite is described by McGlynn (1971) as being massive, fine grained, reddish in colour, consisting of plagioclase, hornblende, some biotite and variable amounts of quartz.

The mineralization occurs in a steeply dipping, curving shear/breciated zone which strikes northeasterly and is 105m in length, 1 - 2m in width and depth unknown. This zone is believed to be contemporaneous with the host intrusion (Badham, 1977). The mineralization occurs as patches, veins, fracture fills at fracture intersections and disseminations. Chalcopyrite, pyrite, cobaltite, galena, niccolite, pitchblende, carbonate minerals, malachite, erythrite, and annabergite are all present

in varying amounts. The distribution of the mineralization is erratic and trench samples assayed for U_3O_8, gave trace to 0.4%, Co:0.1% to 0.4% and Cu:tr to 1%.

Thin section examination of the host rock reveals that the mineralization replaces and extensively alters the host. A majority of the feldspar grains are replaced by carbonates, while remaining feldspar grains are altered to chlorite and sericite. The host rock may be a monzonite in composition, but a positive identification was not possible due to extensive replacement and alteration. This alteration and replacement of the host indicates that the mineralization was a post-crystallization phase of the laccolith. The alteration/replacement is similar to the carbonate-sericite-chlorite-hematite assemblage described by Badham (1977) as alteration caused by a late phase differentiate on the top of the laccolith.

5. C. C. Claims (71)

The C. C. Claims occur 32km southwest of the Town of Snowdrift on the Labelle pennisula (Figures 1 and 7), and the mineralization is within another laccolith of the Caribou intrusions. The host rock has been determined to be a quartz monzonite by the author by thin section petrography. Andesine and microcline are major constituents (75%), and these feldspars are in various stages of sericitization, chloritization and replacement by calcite.

The ore of this occurrence is present in veins in a WNW joint set which cuts the host rock. The mineralization consists of cobalt, nickel arsenides and sulphides plus uraninite and uranium secondary minerals. This mineralization totally alters and replaces the host. The altera-

tion products consist of sericite, chlorite and abundant late calcite replacing most minerals. These veins are thought to represent the last magmatic differentiates and hydrothermal solutions of the host intrusion (Badham, 1977).

6. Reliance (Rel., P 4, 5, 6, and 7)

Oladegbule (1971) and Bucknell (1975) describe the local geology of these occurrences which were discovered by Vestor Exploration Ltd., west of Meridian Lake (Figures 1 and 8). Within this area there has been movement along steeply dipping northeast trending faults, such that the granite basement and the Hornby Channel Formation are uplifted against younger sediments of the Kahochella and the Pethei groups. Fold structures between the faults are open and plunge gently to the northeast. The uranium bearing unit occurs on the northwest limb and in the core of the "Meridian Lake Anticline", and the U-occurrences are located at the nose of the plunging anticline.

The uranium mineralization is confined to a zone 335m long and 125m wide, parallel in strike to the host beds and less than 30m from a major regional splay fault. The host is the Hornby Channel Formation which is 30 to 90m thick in this area and lies unconformably on Archean basement granites. The host lithology is a feldspathic sandstone which locally grades into a granule conglomerate. It is a poorly sorted, angular to subangular, fine to coarse grained, red to buff coloured unit. The matrix is composed of sericite and partly sericitized feldspar fragments, with a marked increase of hematite in the martrix near the ore bodies. The unit is usually massive-bedded and contains some thick bed units with crossbed sets which indicate a unimodal S. W. paleocurrent

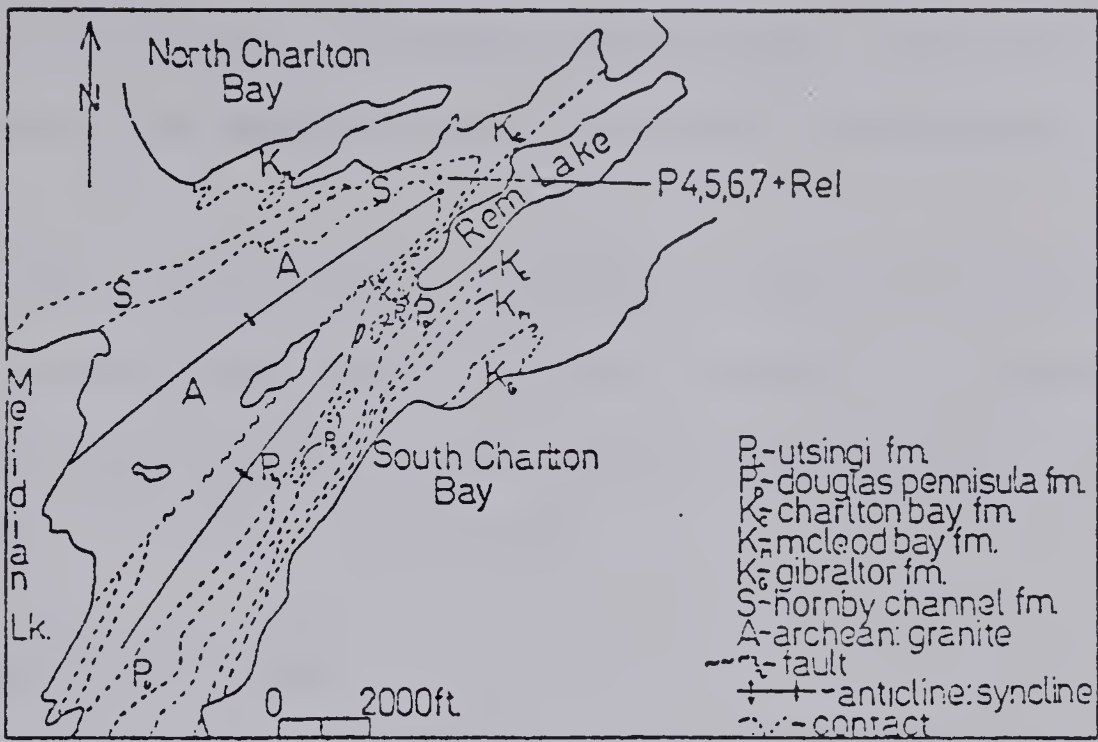


Figure 8

The Local Geology of the Reliance Deposit.
(Oladegbule, 1971)

direction, in agreement with Hoffman (1969 & 1968). The sands are very immature due to the feldspar content and bimodal distribution of the grain size.

The uranium mineralization is located in very strong radiometric anomalies of relatively small dimensions (less than 3 by 3 metres). The uranium mineralization is associated with hematite, and replaces the matrix totally. Grades of U reach 10%.

7. MDM and DM Claims (45)

This set of claims is located at the southeast end of Union Island (Figure 3), and the uranium mineralization occurs in a 0.3 to 0.7m wide silicified fault zone (McGlynn, 1971) which is characterized by intense brecciation and hematitization of a dolomite of the Union Island Group. The uranium is associated with hematite, minor pyrite and trace amounts of chalcopyrite and galena. Grades from grab samples assayed between .01 and .2% U_3O_8.

II. NATURE OF THE MINERALIZATION

A. MINERALOGY AND PARAGENESIS

The relationship between the uranium oxides and the sulphide mineralization of each deposit is important when evaluating the U-Pb isotope systematics. Examination of a polished section was undertaken for each isotopically and chemically analyzed sample. The ore microscopy did not involve an elaborate examination of each sample, but emphasis was placed on determining the relationship between the uranium oxides and the remaining ore and the host.

Morton (1974), Walker (1977), Oladegbule (1972), and Badham (1977) have studied polished sections, in varying detail, of the mineralization of the subject deposits. Morton (1974), with the aid of Walker and Olade, published a table (Table I) on the mineral paragenetic sequence of the Simpson Island, Toopon Lake and Reliance deposits while the remaining deposits were examined by Badham (1977) and the author. The author would like to add some additional observations to those of R. D. Morton (1974) on the mineral assemblages of the deposits.

In the Simpson Island samples uraninite and pyrite are abundant ore minerals while chalcopyrite, hematite and coffinite occur in relatively minor amounts. Galena is present at crystal edges and microfractures within uraninite grains, as speckles within coffinite and in voids present at times of mobilization. Berman (1957) deduced that radiogenic lead in the form of PbO (orthorhombic) is exsolved along uraninite crystal boundaries as a result of incompatiblity within the uraninite.

Table I. Paragenetic Sequence of the Uranium Deposits in the East Arm (Morton, 1974)

DEPOSIT	PHASE I	IA	II	III	IV	SUPERGENE OXIDATION at SURFACE
SIMPSON ISLANDS	ilmenite magnetite		pyrite chalco-pyrite cobaltite sphalerite	anatase hematite uraninite	coffinite galena quartz	goethite covellite secondary uranium minerals
RELIANCE	ilmenite magnetite		pyrite chalco-pyrite cobaltite safflorite arseno-pyrite	hematite uraninite brannerite calcite barite	coffinite galena	secondary uranium minerals
TOOPON LAKE	ilmenite carbonaceous material pyrite	anatase	pyrite chalco-pyrite cobaltite	brannerite hematite uraninite	galena quartz	goethite covellite secondary uranium minerals
REX	magnetite ilmenite uraninite pyrite		anatase hematite galena			
C.C. & FAIR	SEE TEXT					
UNION ISLAND	pyrite		hematite pitchblende	galena		

structure (cubic). After the PbO is exsolved, it may change to PbS by reaction with available sulfide.

Goethite rims are common on pyrite grains in the Simpson Island samples. This indicates that weathering processes are affecting the ore. Petrographic work shows that the ore is present only in the matrix of the host granule-stone. The matrix is not altered by the ore. The degree of alteration and the mineral assemblage indicates that the mineralization was deposited under low temperature conditions.

In the Toopon Lake samples ilmenite/anatase and carbonaceous material provide the deposition sites for both pyrite and uraninite (Plate I, No. 1 and 2). Galena (radiogenic) again is present. Quartz overgrowths appear to have sealed off the porosity of the host after the mineralization was in place.

It is known that deposition of uranium minerals at carbonaceous material sites occurs in roll-type U. S. uranium deposits (Finch, 1967). Reynolds, Goldhaber and Grauch (1977) have shown that Ti oxides within ore from roll-type deposits in south Texas, also form deposition sites. To an extent the mineral assemblage and paragenetic sequence of the Toopon ore is similar to roll-type deposits in the United States, however, one must take into account the differences in host and source rocks.

The Reliance ore has hematite, pyrite, and uraninite as main components of the ore, while minor amounts of chalcopyrite, cobalt-nickel arsenides and barite are present (A typical example is shown on Plate I, No. 3). The mineralized host is completely altered, and the matrix is replaced by the ore (Plate I, No. 4). Feldspar grains in the matrix have been brecciated and sericitized by the mineralization. The mineral assemblage and paragenesis (Table I) and the ore extensively replacing

PLATE I

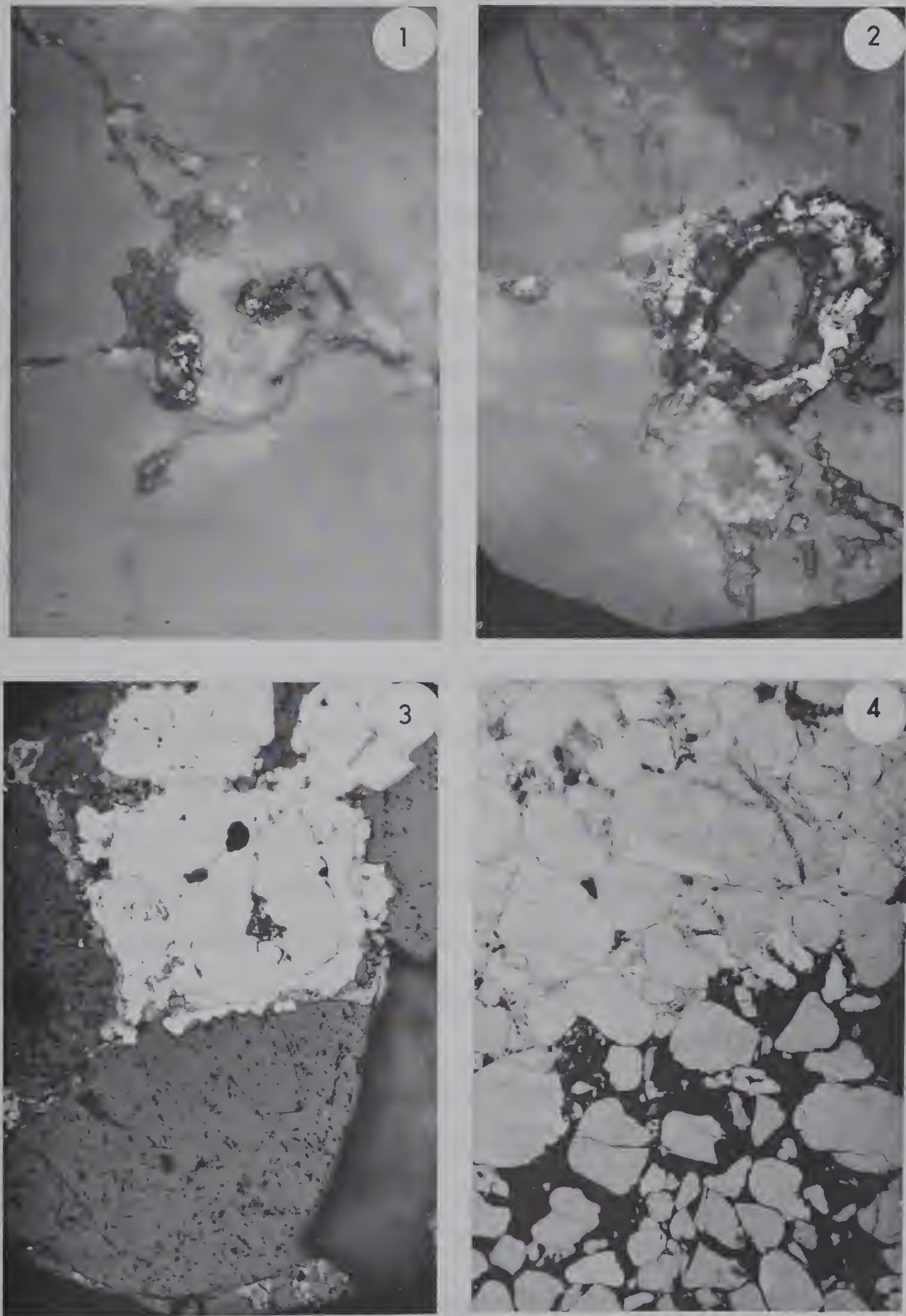
1) Toopon Lake (TLP2), X160, uraninite replaces both pyrite and anatase.

2) Toopon Lake (TLX), X40, anatase stained by 2° uranium minerals, uraninite speckled by radiogenic galena, ilmenite replaced by anatase which is replaced by pyrite and then replaced by uraninite.

3) Reliance (P4-2), X63, uraninite rimming and replacing a pyrite grain and a small grain of chalcopyrite.

4) Reliance (P4), X4, mineralization replacing matrix.

PLATE I.



and altering the host points to a high temperature, aqueous (hydrothermal) emplacement of the ore.

The mineralization of the Rex, C. C. and Fair deposits in the quartz monzonite laccoliths of the Caribou intrusions represents the last magma differentiate phase according to Badham (1977). The Rex ore shows a simple paragenesis (Table I) where apatite, actinolite, magnetite, ilmenite, uraninite and pyrite were formed comtemporaneously (as shown on Plate II, No. 3). Gamma ray scintillometer work on magnetic separates of this ore indicated that radioactivity was closely associated with this portion. Polished work also confirmed that uraninite and magnetite are always in close association.

The mineralization at the C. C. and Fair occurrences contains Co-Ni-As-Ag-U and is hosted by the alkaline quartz monzonites. This mineralization replaces the host indicating it is a late phase and is associated with extensive carbonate and sericite replacement (alteration) and carbonate veining (shown in Plate II, No. 1 and 4). The uranium phase at both deposits is uraninite ± sulfides (ie., pyrite). Ore microscopic work by Badham (1977) on the C. C. Claims shows that carbonates and arsenides are cored by quartz and calcite and associated with tetrahedrite, silver minerals, uraninite, secondary uranium minerals and rare molybdenite. This description could also be used for the Fair Claims, which appear to be similar. Interestingly, all these phases occur in the Co-Ni-Ag-As-U deposits at Great Bear Lake, but the uraninite phase precedes the arsenide phase in these deposits (Rich et al, 1977). It appears these deposits are high temperature hydrothermal deposits which have similarities to classic Co-Ni-Ag-As-U deposits.

The MDM claims have uranium mineralization in a fault zone. The

PLATE II

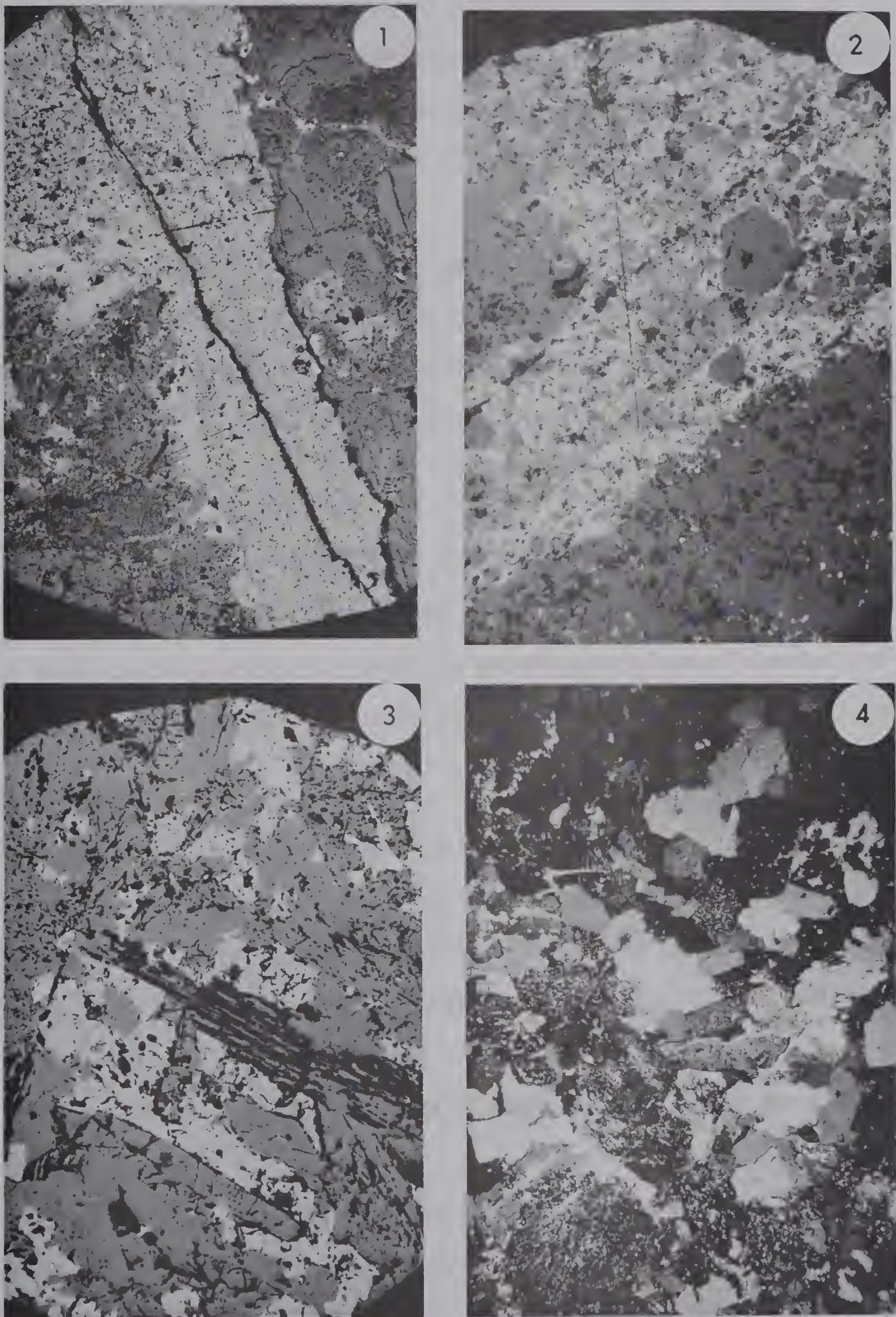
1) Fair, X4, typical view of a replacement of Co-Ni-As ore in the host.

2) MDM, X63, pitchblende and pyrite brecciating and replacing host.

3) Rex, X4, typical view of ore, with actinolite, magnetite and uraninite present.

4) Fair, X4, quartz monzonite host altered to carbonate.

PLATE II.



host carbonate is brecciated and hematitized extensively in the ore zone (see Plate II, No. 2). The mineral assemblage is rather simple and hematite, pyrite and pitchblende compose the dominant ore, with the pitchblende being ooloid or colloform in texture. The simple mineral assemblage and hematitization points to a high temperature aqueous formation.

The ore microscopic work indicates that there are a variety of different types of uranium deposits to be analyzed geochemically and isotopically. The primary uranium oxides are emplaced in one phase, and only at the Reliance and Simpson Islands deposits are they modified to coffinite.

B. TRACE ELEMENT GEOCHEMISTRY

For possible geochemical correlations between the deposits, Ag, Ba, Be, Co, Cr, Cu, Mo, Ni, TiO_2, V and Zn were analyzed. The determination of these trace elements is useful in grouping each set of samples and possibly relating these groups to the U-Pb isotope systematics.

1. Sampling

The location of each sample is not known within a given trench, but geographic/geologic location of the trench has been ascertained (Chapter I). There has been abundant sampling of each uranium-bearing trench, such that a homogeneous representative sample of the mineralization could be obtained.

Samples for isotope and chemical analysis were chosen by the following criteria:

a) appearing to be representative of the ore sample

b) lack of secondary uranium products

c) lack of hematitization

d) low amounts of sulphides (ie. pyrite)

e) their general unweathered appearance

Thus the samples used in this study were the most representative and unweathered samples obtainable.

Samples from the Simpson Islands, Toopon Lake, Reliance, Union Island and the C. C. Claims underwent the same preparation procedure (Table II). These samples were broken by hammer or diamond-sawed into 2cm cubes. The cubes were inspected for any alteration using a hand lense (x 16), any severely altered or unrepresentative sample of the ore was rejected. The samples were then crushed in a jaw crusher, and finally reduced to less than minus 100 mesh in a swing mill. Contamination was avoided by cleaning each machine thoroughly between samples. The crushed samples were divided into 16 or 32 piles on a clean sheet of white paper. Using a spatula, a sample was taken from each pile until a twenty gram vial was approximately half full. From this vial, samples were obtained for isotope and geochemical work where leaching was required.

With each sample a representative thin section and/or polished section was prepared from which the types and phases of uranium mineralization could be determined (see previous discussion on mineral paragenesis). Each section was also useful in determining qualitatively what trace elements may be present.

2. Analytical Method

One or five gram representative samples for geochemical analysis were either decomposed with concentrated HNO_3 and HF in teflon beakers or leached by concentrated HNO_3 and H_2O (see Table II). All these samples were diluted to a known volume.

Table II. Alteration and Sample Preparation

SAMPLE NUMBER	ALTERATION of HAND SPECIMAN	EXTENT of ALTERATION	PREPARATION for ISOTOPE WORK	PREPARATION for GEOCHEMICAL WORK	COMMENTS
T4-1	fresh	slight	leached 1g.sample with conc. HNO_3	dissolved in conc. HF & conc. HNO_3	
T4-2	fresh	slight	as above	as above	
T4-3	up to 5% 2° U minerals	moderate	as above	as above	choose less altered parts for work
T6-1	fresh	slight	as above	as above	
T6-2	fresh	slight	as above	as above	
T6-3	fresh	slight	as above	as above	
T9-1	1% 2° U minerals	moderate	as above	as above	
T9-2	100% 2° U minerals	extreme	as above	as above	
T10-1	fresh	slight	as above	as above	
P4-1	extensive hematitization	moderate	as above	as above	no secondary U minerals
P4-2	as above	as above	as above	as above	as above
P5-1	as above	as above	as above	as above	as above
P6-1	as above	as above	as above	as above	as above
P7-1	as above	as above	as above	as above	as above
REL"A"	fresh	slight	nonmagnetic fraction of heavies,		quartz residue & possible ilmenite
REL"B"	as above	as above	black vitreous uraninite dissolved 1ml. conc.		as above
REL"C"	as above	as above	HNO_3& 1ml. HF		as above
11-1	minor am't 2° U minerals	slight	leached in conc. HNO_3	leached in conc. HNO_3	coarse fraction > 100 mesh
11-3	abundant 2° U on sample	moderate	as above	as above	fine fraction < 100 mesh
28-1	anabergite & erythrite common	moderate to extreme	handpicked fresh pitchblende dissolved in conc. HNO_3		no residue after pitch. dissolved
28-2	2° U minerals	moderate	handpicked pitch. speckled with pyrite dissolved in conc. HNO_3		pitch. had brownish-black colour, no residue after being dissolved
28-3	fresh in calcite vein	none	handpicked galena leached in conc. HNO_3		large galena cube with minor am't of cpy.,cov., cc.,&tetrahedrite,no residue
45-3	fresh	slight?	leached conc. HNO_3	leached conc. HNO_3	
45-4	extreme hematitization,very minor 2° U minr.	moderate	as above	as above	minor calcite veinning
71-2A	fractures with 2° U minerals & anabergite	slight	handpicked brownish-black pitch. dissolved conc. HNO_3		pyrite in association minor am't(1%), no residue
71-3	fresh pitch. vein	slight	handpicked black vitreous pitch. dissolved in conc. HNO_3		py.&cpy. in association minor am't of calcite no residue
TLP2-1	minor am't(1%) 2° U minerals	moderate	leached in conc. HNO_3	leached in conc. HNO_3	hematite rinds avoided
TLP2 TLP3 TLX	minor am't of 2° U	moderate	sieved to -80 mesh magnetically seperated density seperated with methyl iodide then hand-picked black vitreous uraninite	dissolved in conc. HF & HNO_3	residue after HNO_3 treatment, of quartz&very minor amount of ilmenite

The samples were analyzed on a Perkin-Elmer Atomic Absorption Spectrometer Model 503. The absorbance data was recorded by chart as well as visually from a digital display. The elemental concentration was determined by comparison with standards of the element run at the beginning and end of each run. The standards were plotted as a standard curve from which element concentration was determined.

3. Comparison with Standards

U.S.G.S. and G.S.C. geochemical rock standards were run in conjunction with the samples, and the results are shown on Table III. Nickel and vanadium show slightly enhanced values, while zinc appears to be somewhat low. Agreement between published values (Flanagan, 1973 and Abbey et al 1975) and measured values are generally within twenty percent of the amount present, despite the fact that the Canadian standards MRG-1 and SY-2 are slightly heterogeneous (Abbey et al, 1975). The standard SY-2 was excellent for comparison since the uranium-bearing minerals and the associated trace elements of this syenite standard were present in similar amounts and proportions in the samples.

4. Results

The results of trace element analyses of the deposits are compiled on Table IV. The samples from the Fair (28) and C. C. (71) Claims were not analyzed for trace element content since a fully representative sample of these veins could not be obtained. Each deposit has enriched trace element content (aside from uranium) relative to the other occurrences and these enriched elements are listed on Table V.

The Simpson Islands samples are enriched in TiO_2, this is due to TiO_2's concentration in detrital minerals (ie. principally ilmenite). It should be mentioned that gold has been analyzed in Walker's (1971)

Table III. Analysis of Standard Samples (to test accuracy)

ELEMENT	ANALYZED ABUNDANCE (ppm)	STANDARD	PUBLISHED VALUES (ppm) mean	range
Ba	474	SY#2	460	174-740
	35	MRG-1	55	37-190
	752.5	USGS BCR-1	675	
Be	22.75	SY#2	10-30	
	0.75	MRG-1		0.1-30
	1.25	USGS GSP-1	1.5	
Co	35.75	SY#2	10	1-26
	103.5	MRG-1	87	60-125
	126	USGS DTS-1	133	
	25	USGS BCR-1	38	
Cu	78	USGS DTS-1	70	
Cr	9.5	SY#2	10	6-32
Mo	2.5	SY#2		1-7
	5	MRG-1	5.4	1-13
	tr.	USGS DTS-1	0.2	
Ni	18.75	SY#2		3-39
	206.2	MRG-1	200	104-251
TiO_2	1625	SY#2	1500	1200-2500
	33050	MRG-1	37500	32700-40100
V	62.5	SY#2	40	20-56
	612.5	MRG-1	520	400-596
Zn	175	SY#2	250	171-380
	142.5	MRG-1	185	158-225
	37	USGS DTS-1	45	

Table IV. Elemental Concentration in Samples

SAMPLE NUMBER	ELEMENTAL CONCENTRATION (ppm) U	Pb	Ba	Be	Co	Cr	Cu	Mo	Ni	TiO_2	V	Zn	As
T4-1	13771	1420	59	2.9	64	17.5	275	7.5	6.2	812	16	8	0
T4-2	13351	1100	59	2.2	257	45	50	15	25	2750	44	n.d.	0
T4-3	63052	324	55	2.7	50	17.5	75	15	3.1	812	19	4	0
T6-1	43619	954	78	1.9	36	17	0	10	3.1	325	3.1	3.5	tr
T6-2	9803	729	64	1.9	53	16	tr	17	6.2	500	6.2	7.5	tr
T6-3	9081	848	40	1.1	21	14	tr	0	3.1	925	6.2	4.5	0
T9-1	402	35	35	0	39	10.5	2200	52	0	325	12	7.5	0
T9-2	17446	310	191	2.5	21	26	1898	5	6.2	850	19	8	0
T10-1	7225	986	15	1	46	25	tr	tr	6.2	937	19	6	tr
45-3	85	204	512	1.3	17	7	10	2.5	30	0	50	48	0
45-4	25037	4668	63	0.4	29	8	70	6	25	180	2740	29	.05
11-1	2995	80	6	1.4	9	32	15	0	25	110	165	11	0
11-3	3435	102	6	2.3	14	73	10	2.5	45	120	290	14	0
TLP2-1	7627	163	454	0.5	63	19	27.5	253	7.5	150	12	5	.05
TLP2			246	0.25	34	29	36	319	12.5	300	0	5	.9
TLP3			184	0.4	39	16	36	1100	10	120	19	4	.2
TLX			265	0.65	40	23	232	385	10	100	12	6	1.25
P4-1	12247	1185	1944	1.9	143	70	75	2.5	62.5	437	12	5	0
P4-2	20199	1223	650	3.1	190	34	1023	2.5	31	300	12	4	0
P5-1	61405	4681	837	1.7	150	43	288	27.5	31	575	19	6	tr
P6-1	108539	4411	2000	2.9	227	26	395	67.5	44	550	12	5	0
P7-1	76559	9120	162	1.6	93	70	50	37.5	31	387	12	5	0

Table V. Trace Element Characterization of the Analyzed Uranium Mineralization

Deposit or Claims	Relative Amount of Each Element: Enriched	Moderate	Low	Variable
Simpson Islands	TiO_2	Ba, Co, Cr	Ni, Be, Mo, Zn	Cu, V
MDM and DM	Zn, V	Co, Ni	Mo, Be, Cu, Cr	Ba, TiO_2
Toopon Lake	Mo, Ag	Ba, Co, Cr Cu	Be, Ni, TiO_2 V, Zn	
Rex	V	Cr, Ni, Zn	Be, V, Zn Ba, TiO_2, Cu	Mo
Reliance	Cu, Ba Co, Cr	Ni, TiO_2	Be, V, Zn	Mo

initial study of the Simpson Island's samples by Crest Laboratories (Edmonton) that ranged in values from trace to 0.69 oz/t (Walker, 1977). Copper is present in enriched amounts in the T9 samples but is erratic in distribution and abundance in the remaining Simpson Islands samples.

The MDM and DM samples are enriched in V and Zn. Both of these elements are geochemically mobile and vanadium in particular behaves chemically similar to uranium. Vanadium is particularly enriched in sample 45-4 which is from the main ore body.

The Rex samples from the actinolite-apatite-magnetite veins are enriched in vanadium and chromium.

In the Toopon Lake mineralization Ba, Mo, and Ag are present in enriched amounts. The barium content may represent the cement component within the host orthoquartzite while Ag and Mo are associated with the uranium deposition.

The Reliance occurrences are enriched in Ba, Co, Ni, Cr and possibly Mo. Cobalt, nickel and chromium are thought to be associated with the uranium mineralization while barium may be related to the host rock background.

In the clastic-hosted mineralization of the Simpson Islands, Toopon Lake and Reliance; Ba, Be, Cr, TiO_2 and Zn may represent values close to background. The Be and TiO_2 content is dependent on grain size, where it increases in abundance from the fine grain clastic of Toopon Lake to the coarse grain sand of Reliance to the very coarse grain Simpson Islands conglomerate. Barium is present in background values in the Toopon and Simpson samples, however the Reliance samples may be enriched with this trace element. Barium is of a highly variable nature in sediments, and background values are difficult to define. Zinc and chromium

are present in the clastic samples at background values.

The purpose of indicating the relative enrichment of trace elements in each mineralization was to accentuate the geochemical differences between each uranium deposit.

5. Grouping or Correlation

The "enriched" trace elements were graphed versus each other or versus percent uranium. The results of these plots are shown in figures 9 to 13 for all the analyzed occurrences. The common salient feature of all these plots is that the different deposits plot into their own fields with little overlap.

As a result of the heterogeneous distribution of uranium and trace elements in the deposits, the fields in uranium versus trace element plots tend to be large and indistinct in comparison to trace element plots. There appears to be no direct relationship between trace elements and uranium concentration in most of the deposits with the exception of Mo and U from the Reliance deposit (Figure 11). There is a statistical linear relationship between the U and Mo concentration in the Reliance examples, and the line has a regression of 0.99 indicative of good correlation.

The correlation plots graphically show the difference in trace element geochemistry between each deposit.

6. Comparison with Known Deposits

Table VI shows the trace element content of selected uranium deposits from the western world. These deposits were chosen due to host similarities (clastic) and the fact that they are representative, multiply-sampled deposits analyzed for trace elements. The reader is reminded

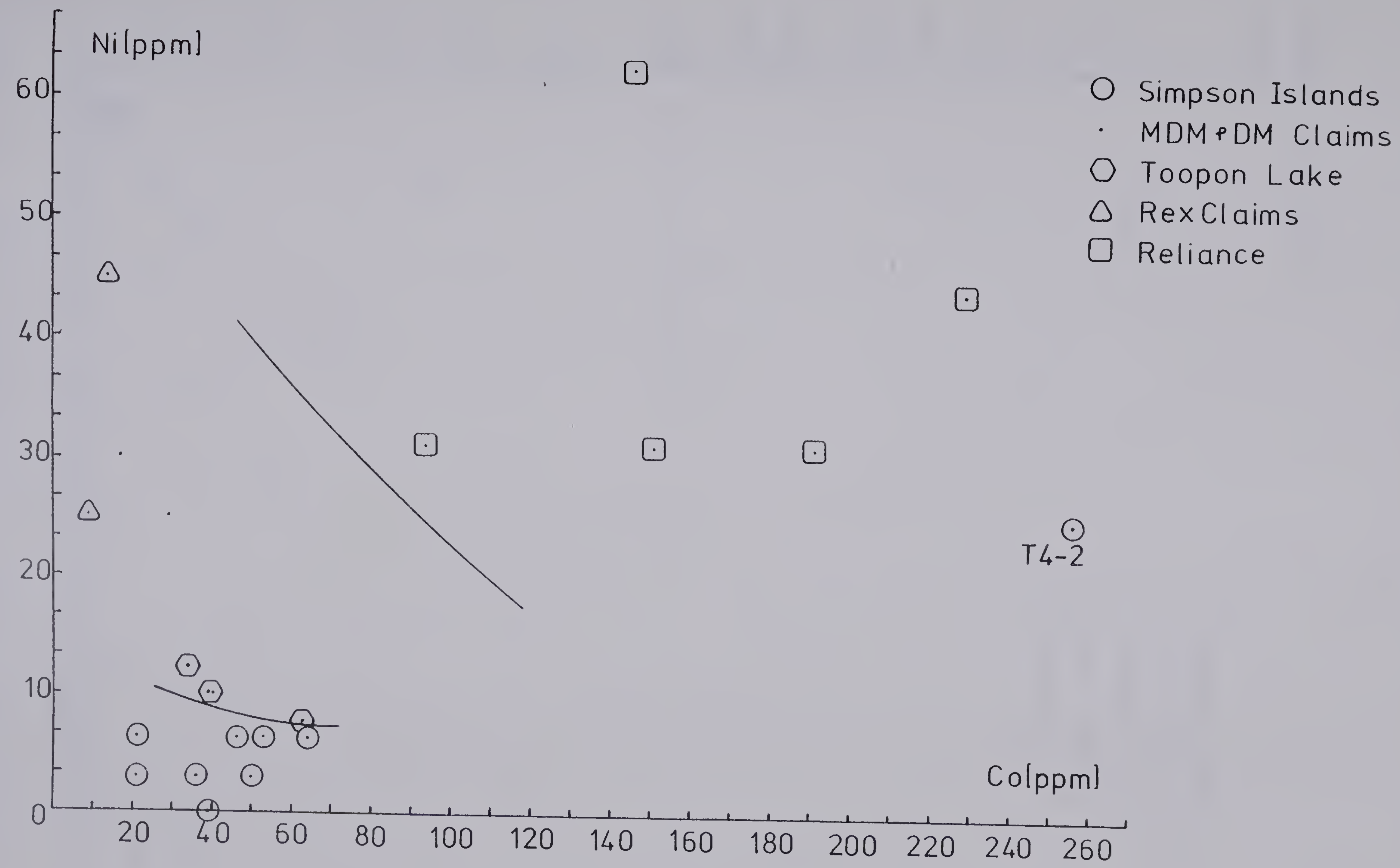


Figure 9. Elemental Correlation Plot, Cobalt versus Nickel

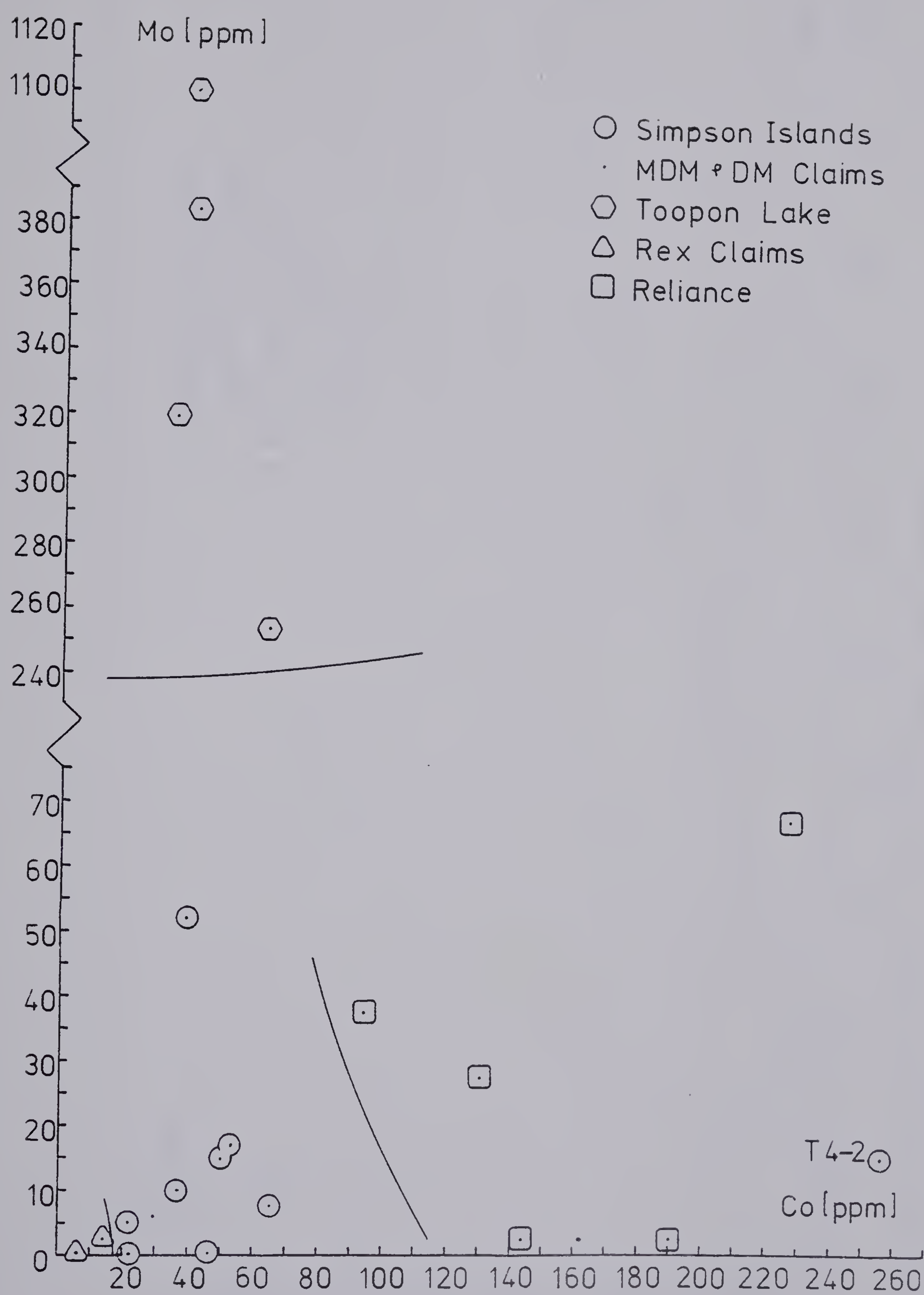


Figure 10. Elemental Correlation Plot, Cobalt versus Molybdenum

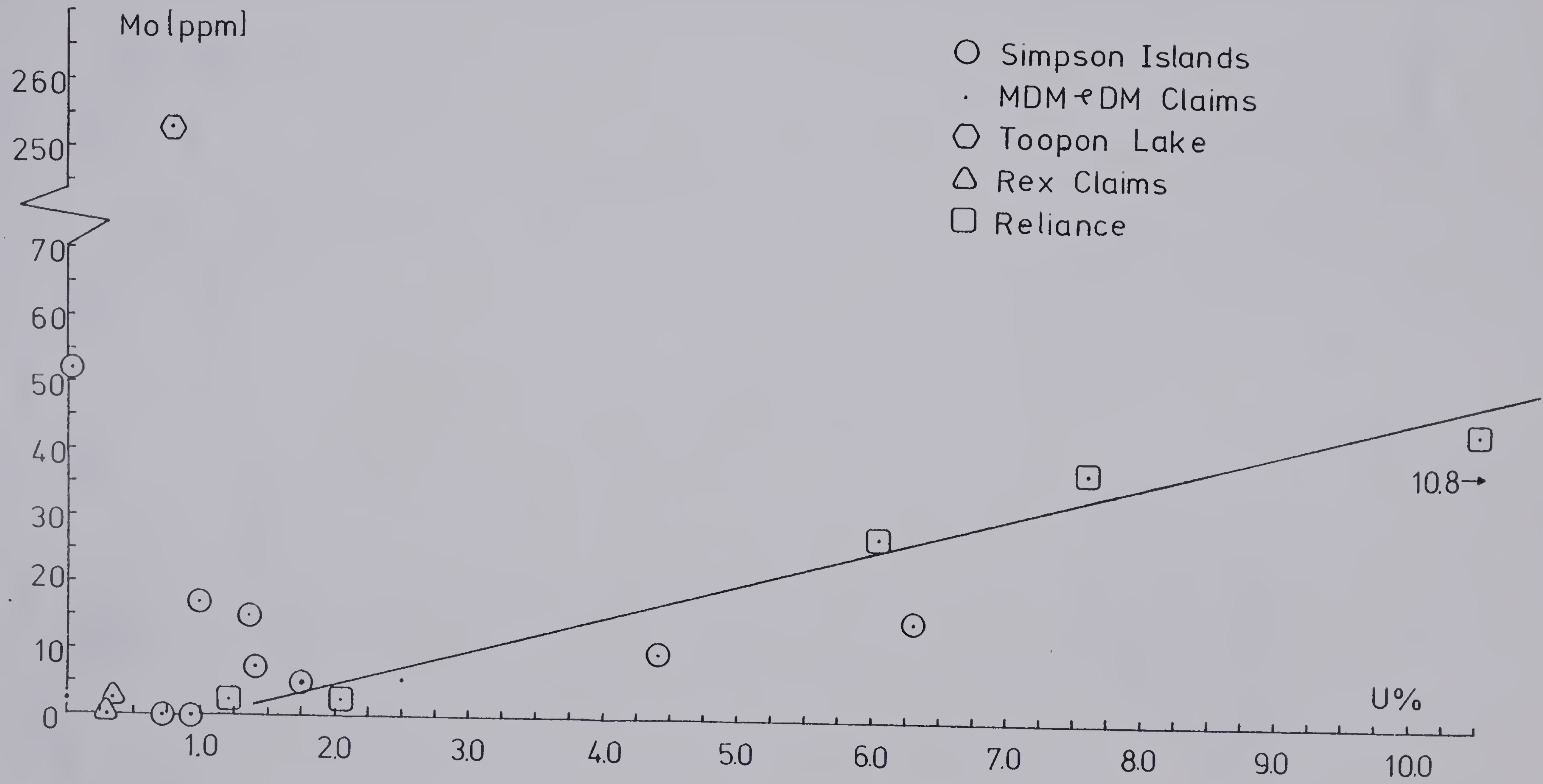


Figure 11. Elemental Correlation Plot, Molybdenum versus Uranium

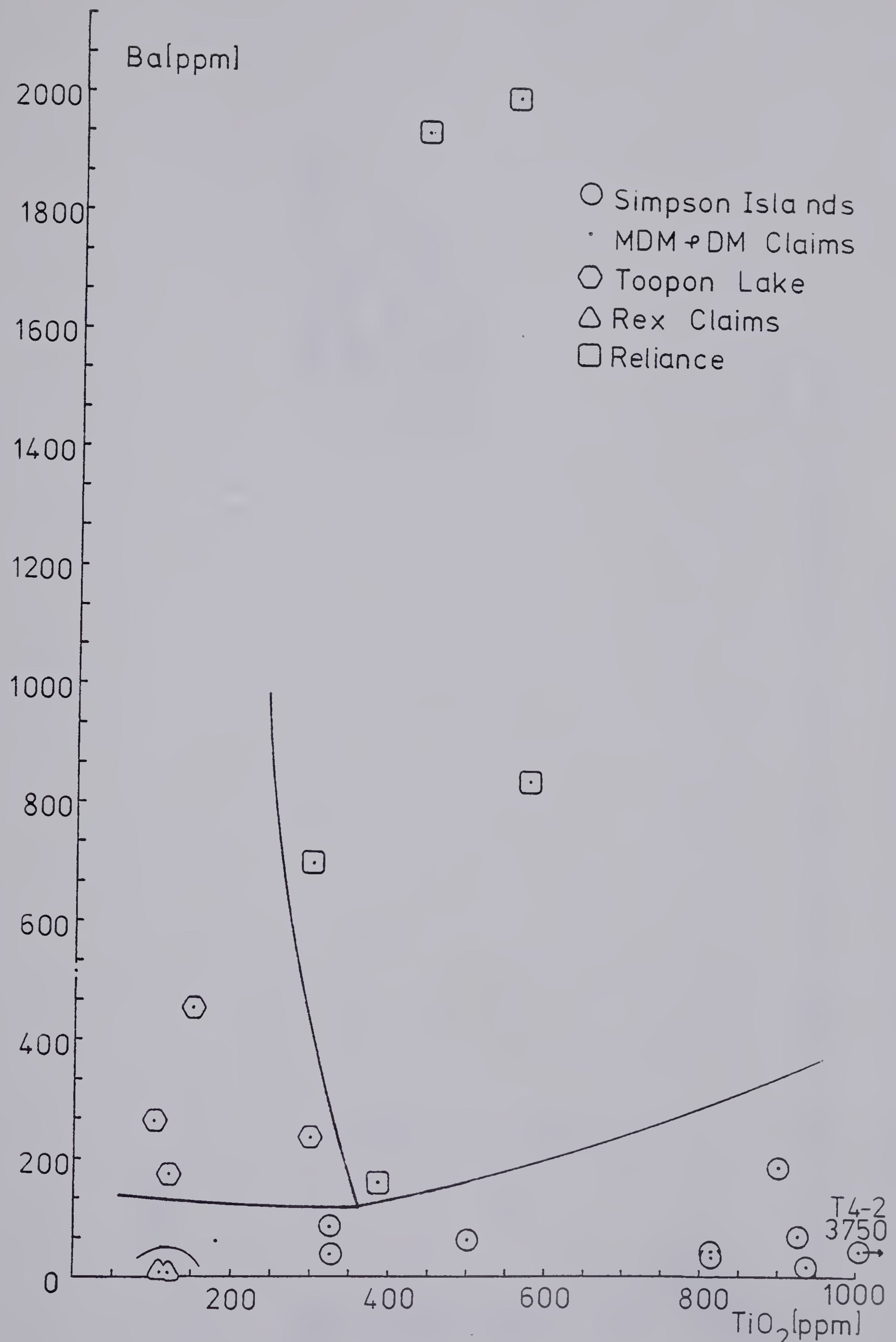


Figure 12. Elemental Correlation Plot, Barium versus Titanium Oxide

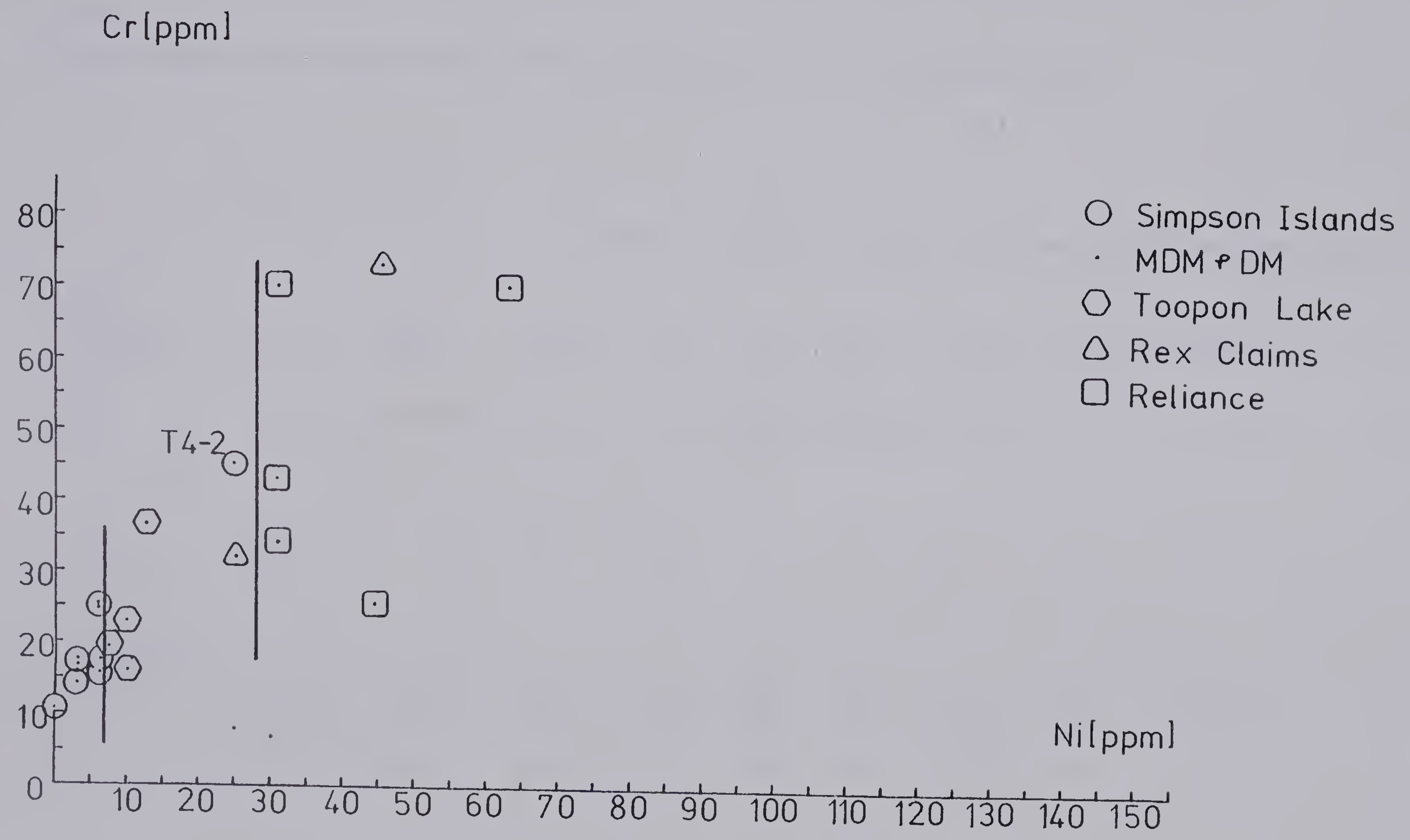


Figure 13. Elemental Correlation Plot, Chromium versus Nickel

Table VI

Trace Element Characterization of the Analyzed Uranium Mineralization

(Means of oxides or elements in ppm, values in parenthese's indicate ranges in ppm)

Deposit	U_3O_8 or U*	TiO_2 or Ti*	Ba	V	Mo	Co	Ni	Cr	Au	Ag
Placers										
Blind River -Elliot Lake (Roscoe, 1968)	(10-17300)	5100* (500-9500)	900 (300-2000)	60 (0-110)	30 (10-140)	200 (10-400)	170 (10-300)	50 (10-110)	tr to erratic highs tr. 1 oz./ton	(006-.24oz/t)
Dominion Reefs (Hiemstra, 1968)	(90-90980)	(2100-66100)	----------	-------	292 (86-430)	178 (27-2224)	153 (52-1956)	33	(tr-130 dwt/t)	(1-30)
U. S. "Roll-type"										
Chinle Fm.	1600*	------------	660	1600	35	35	34	31	-------------------	
Morrison Fm. (Finch, 1967)	1500*	------------	750	6900	20	12	10	16	-------------------	
Analyzed Deposits This study										
Simp. Is.	402-63052*	325-3750	15-191	3.0-44	tr-52	21-257	0-25	14-45	tr-.69 oz/ton	0-tr
Rel.	12247-108539*	300-575	162-2000	12-19	50-1028	93-227	31-62	26-70	-------------------	0-tr
T.L.	7627*	100-300	184-454	0-19	27-232	34-63	7.5-12.5	16-29	-------------------	.05-1.25

that source rock variation of the deposits should be taken into account when comparisons are made.

The Simpson Island deposits have a similar host sedimentation history as the Blind River - Elliot Lake (Roscoe, 1968) and the Dominion Reef (Vos, 1975) deposit's host lithology. The Simpson Islands deposits are enriched in U and Au. Comparison between this occurrence and the selected deposits shows that the Simpson samples are depleted in trace elements (ie. Ba, Co, Ni) with the exception of sample T4-2. As a result of the presence of Au (tr. to 0.69 oz/ton) in the samples at Simpson, one must also wonder whether the uranium content was also detrital in origin. With depleted trace element values it may be concluded that the Simpson Island samples were remobilized while sample T4-2 represents a remnant representative of the original occurrence.

The Toopon Lake occurrences are similar in host lithology to the U. S. roll-type deposits. At Toopon, the uranium mineralization is associated with titanium oxides and carbonaceous material (graphite) which form deposition sites (Mineralogy Chap.). The Toopon Lake geochemistry compares favourably with the U. S. deposits shown on Table VI, however there are contrasts in the V and Mo values. This could be the result of variation in source rock composition.

The Reliance occurrences are hydrothermal deposits due to their high values in U, Ba, Co, Ni, and Mo and the mode of emplacement.

The Union Island and Rex occurrences are high in U and V contents, with Zn also enriched at the Union Island deposit. The Union occurrence is hosted by carbonates. Uranium, vanadium and zinc are highly mobile elements localized in the reducing environment of the host. The Rex samples are enriched in uranium and vanadium; both mobile elements.

Similar examples to the Rex deposits occur in the Camsell River area, N.W.T. (Badham et al, 1976), where vanadium in the magnetite portions in a magnetite-apatite-actinolite intrusion is 0.12% ± .03 (however, uraninite is not reported in these examples).

7. Summary

Each deposit is different geochemically as shown by correlation graphs and difference in relative enriched trace elements. Within each deposit trace elements are heterogeneously distributed.

A difference in source rocks between the East Arm deposits and other deposits from the western world makes comparison difficult but sheds some light on the types of uranium deposits in the East Arm. It appears these deposits cannot be classified on geochemical data alone, since trace element variations are one variable of many used in uranium deposit classification.

III. U - Pb GEOCHRONOLOGY

1. Sampling

Two methods of sampling were used, leaching and handpicking (Table II). As mentioned in the geochemistry chapter, every effort was made to avoid samples with secondary uranium minerals.

2. Analytical Methods

The procedure for obtaining the leached sample solutions has been discussed in Chapter II. The handpicked samples were dissolved in ultrapure concentrated HNO_3 in 10ml teflon beakers. Aliquots for the isotope analyses were pipetted or weighed from the sample solutions. Before the aliquots for uranium or lead analysis were drawn, the abundance of lead was determined by atomic absorption analysis for each sample such that there would be no overspiking on the Pb isotope dilution run. Uranium content was determined for spiking by assuming 75% Pb loss and estimating the age of the sample (from Rb-Sr data).

The Pb isotope ratio and isotope dilution aliquots for each sample were then extracted for Pb by passing the sample through chloride anion columns as described by Krogh (1973). The uranium aliquots were purified by passing through nitrate anion columns (Tatsumoto, 1969). The extracted U and Pb samples were evaporated to dryness, then taken up in $HClO_4$ acid and heated to destroy any organic material. The Pb samples were then loaded by dissolving each in one drop of 2.0 M H_3PO_4 and evaporat-

ing the drop on dried SiO_2 on an outgassed Re filament. The uranium samples were loaded on dried Ta_2O_5 on an outgassed filament.

The samples were run on 12 inch, 90° sector, single focusing, solid source mass spectrometer with facilities for peak switching at pre-set magnet currents. The data for the relative abundances of the isotopes was recorded in chart form. The most stable run (s) were selected to obtain the isotope ratios for processing, the peak heights were measured and ratios derived, an average of 10 to 12 ratios were arrived at, then averaged with precision taken at 2 standard deviations. The measured peaks are often precise to one part in a thousand compared with digital read outs (H. Baadsgaard, pers. comm.).

3. Analytical Results

The analytical results are given on Tables VII and VIII. It should be noted that from the measured 206 Pb/204 Pb ratios that most of the samples contain greater than 99 percent radiogenic 206 Pb and greater than 90 percent radiogenic 207 Pb (assuming the initial 206 Pb/204 Pb and 207 Pb/204 Pb ratios are each 15.0). Since the 207 Pb/206 Pb is of the order of 0.1, errors in measurement of 207 Pb/204 Pb are approximately ten times greater than for 206 Pb/204 Pb. The ppm 206 Pb and ppm 238 U are accurate to better than 1%.

Paired plots of 207 Pb/204 Pb versus 206 Pb/ 204 Pb (Pb-Pb plot) and 206 Pb/238 U versus 207 Pb/ 235 U (concordia plot) are presented for the data on the Simpson Islands in Figures 14 and 15, Toopon Lake in Figures 16 and 17, Reliance in Figures 20 and 21, and the C. C., Fair, Rex deposits in Figures 18 and 19. The discordia and Pb/Pb lines in Figures 14 to 21 are "best fit" lines determined by Pearson's product

Table VII. Isotope Abundance and Atomic Ratios

SAMPLE NUMBER	PPM 238U	235U	206Pb	207Pb	MEASURED ATOMIC RATIOS 206Pb/204Pb	207Pb/206Pb
T4-1	13672.8	97.9	1248.8	114.9	1705±28	.09064±.0004
T4-2	13255.6	94.9	848.2	118.2	445.4±1.3	.12900±.0002
T4-3	62603.4	448.3	280.4	25.4	980.8±8	.08715±.0001
T6-1	43308.6	310.1	850.3	80	2244±15	.09310±.0004
T6-2	9732.9	69.7	655.3	56	2423±5	.08451±.0004
T6-3	9016	64.6	752.3	69.7	1765±13	.09131±.0004
T9-1	400.4	2.9	73.9	7.0	718±8	.08778±.0004
T9-2	17321.8	124	276.4	22.2	1611±20	.07873±.0003
T10-1	7173.9	51.4	896.4	65.8	2432±18	.07251±.0002
TLP2	151060.5	1081.8	32428.7	4272.1	2479±3.7	.11314±.0003
TLP2-1	7573.1	54.2	141.9	15.7	586±3.7	.12546±.0001
TLP3	279905.6	2004.5	8140.5	1958.1	159.8±1.2	.17639±.0003
TLX	178774.7	1280.2	9664.6	1227.9	535.7±1.5	.11884
P4-1	12159.9	87.1	1079.5	101	15820±158	.09037±.00005
P4-2	20054.7	143.6	1107.3	100.9	6254±24	.09062±.00005
P5-1	60968.4	436.6	4151.7	396.2	12680±57	.09497±.00009
P6-1	107766.8	771.7	4038.7	300.5	9403±134	.07402±.0002
P7-1	76013.8	544.3	8231.5	825.1	12640±107	.09974±.0002
REL"A"	151769.6	1086.9	9852	955.2		
REL"B"	160621	1150.2	8826.6	843.5		
REL"C"	137919	987.7	9095.6	879.2		
11-1	2973.7	21.3	69.8	8.2	3560±18	.11738±.0004
11-3	3410.7	24.4	90.4	10.5	4119±18	.11527±.0003
28-1	226444.4	1621.6	14200.9	1692.4	2133±10	.11822±.0002
28-2	148462.2	1063.2	30967.3	3307.7	5851±38	.10623±.00011
71-2A	23615.3	169.1	99.1	9.1	531.7±1.5	.07378±.0002
71-3	103.7	0.7	3229	879.2	140.5±.2	.20873±.0003
45-3	84.9	0.6	175.9	18.4	1254±13	.10262±.0005
45-4	24859.5	178	4209.7	416.3	6245±23	.09835±.0001

Table VIII. Isotope Ratios and Ages

SAMPLE		RATIOS		AGES(millions of years)		
NUMBER	206Pb/238U	207Pb/235U	207Pb/206Pb	206Pb/238U	207Pb/235U	207Pb/206Pb
T4-1	0.1055	1.3317	0.09153	647	860	1460
T4-2	0.0739	1.4178	0.13908	460	896	2220
T4-3	0.0052	0.0645	0.09032	33	63	1430
T6-1	0.0277	0.2928	0.09361	145	261	1500
T6-2	0.0778	0.9116	0.08499	483	658	1320
T6-3	0.0964	1.2251	0.09217	593	812	1470
T9-1	0.2133	2.7641	0.09401	1246	1346	1510
T9-2	0.0184	0.2032	0.07996	118	188	1200
T10-1	0.1444	1.4546	0.07308	869	912	1020
TLP2	0.248	4.4833	0.1311	1428	1728	2110
TLP2-1	0.0216	0.328	0.1099	138	288	1800
TLP3	0.0336	1.109	0.2394	213	758	3120
TLX	0.0625	1.0889	0.1264	391	748	2050
P4-1	0.1026	1.3163	0.09308	629	853	1490
P4-2	0.0638	0.7975	0.09068	399	595	1440
P5-1	0.0787	1.0303	0.09498	488	719	1530
P6-1	0.0436	0.4455	0.07405	275	374	1040
P7-1	0.1251	1.7208	0.09975	760	1016	1620
REL"A"	0.075	0.9978	0.09649	466	703	1560
REL"B"	0.0635	0.8325	0.09510	397	615	1530
REL"C"	0.0762	1.0106	0.09619	473	709	1550
11-1	0.0271	0.4395	0.11753	172	370	1920
11-3	0.0306	0.4874	0.11538	195	403	1890
28-1	0.0725	1.1848	0.11860	451	794	1940
28-2	0.241	3.532	0.10630	1392	1534	1740
28-3		206Pb/204Pb	16.3118	207Pb/204Pb	15.4177	
71-2A	0.0048	0.0609	0.09103	31	60	1450
71-3	35.9611	1343.4	0.27097			3310
45-3	2.3924	34.3567	0.10411			1700
45-4	0.1956	2.6546	0.09841	1152	1316	1590

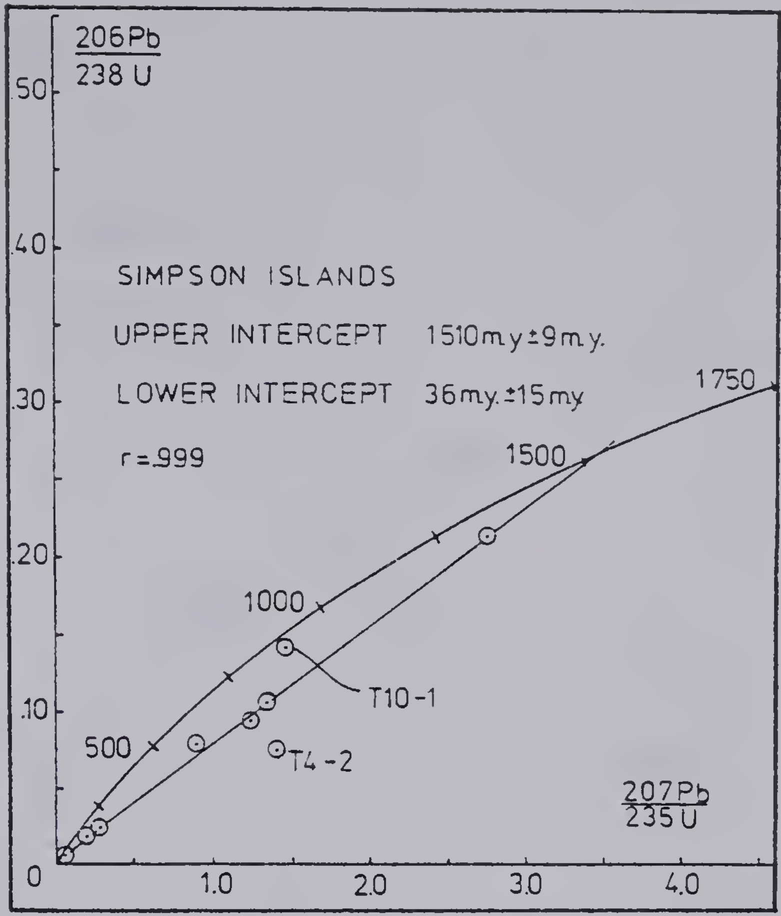


Figure 14. Simpson Islands Samples, U-Pb Concordia Plot.

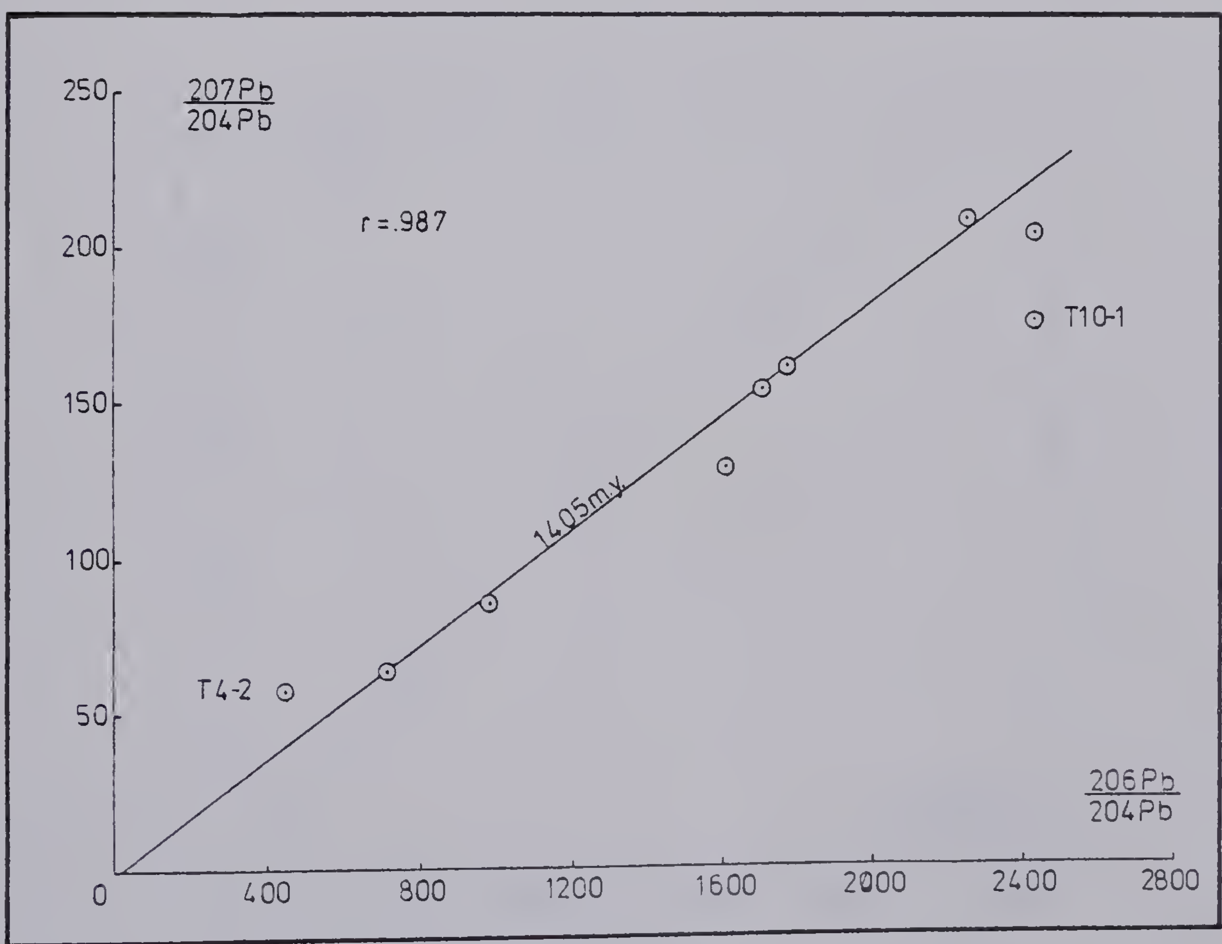


Figure 15. Simpson Islands Samples, 206 Pb/204 Pb versus 207 Pb/204 Pb Plot.

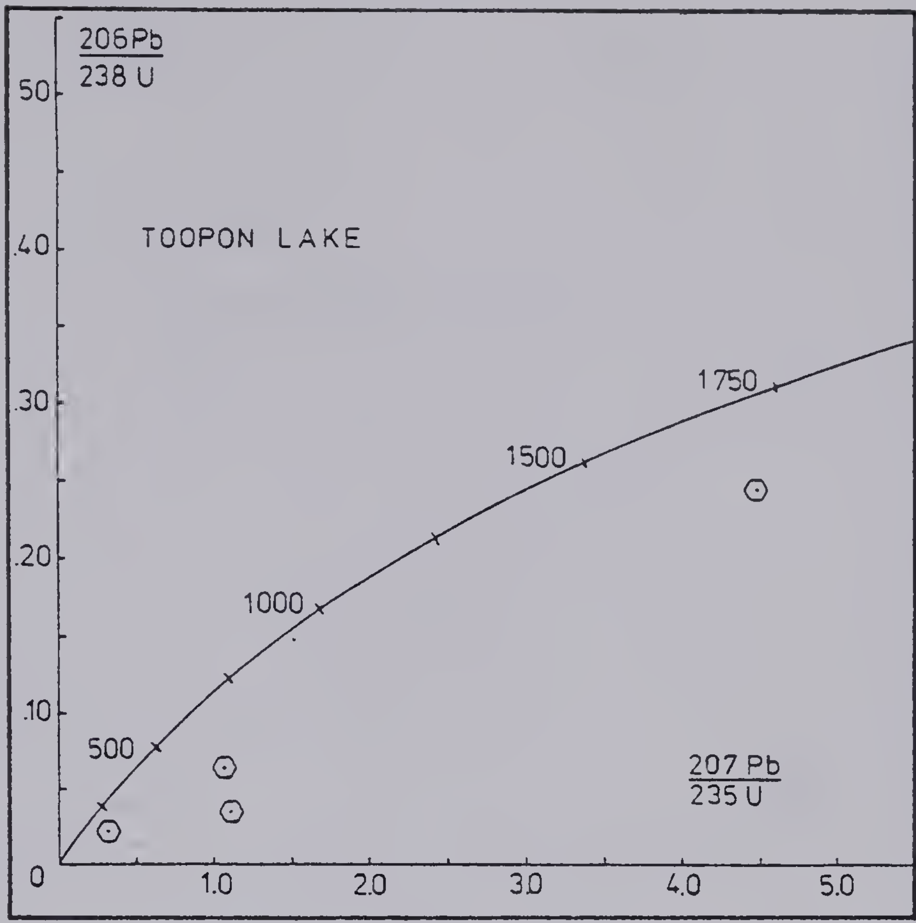


Figure 16. Toopon Lake Samples, U-Pb Concordia Plot.

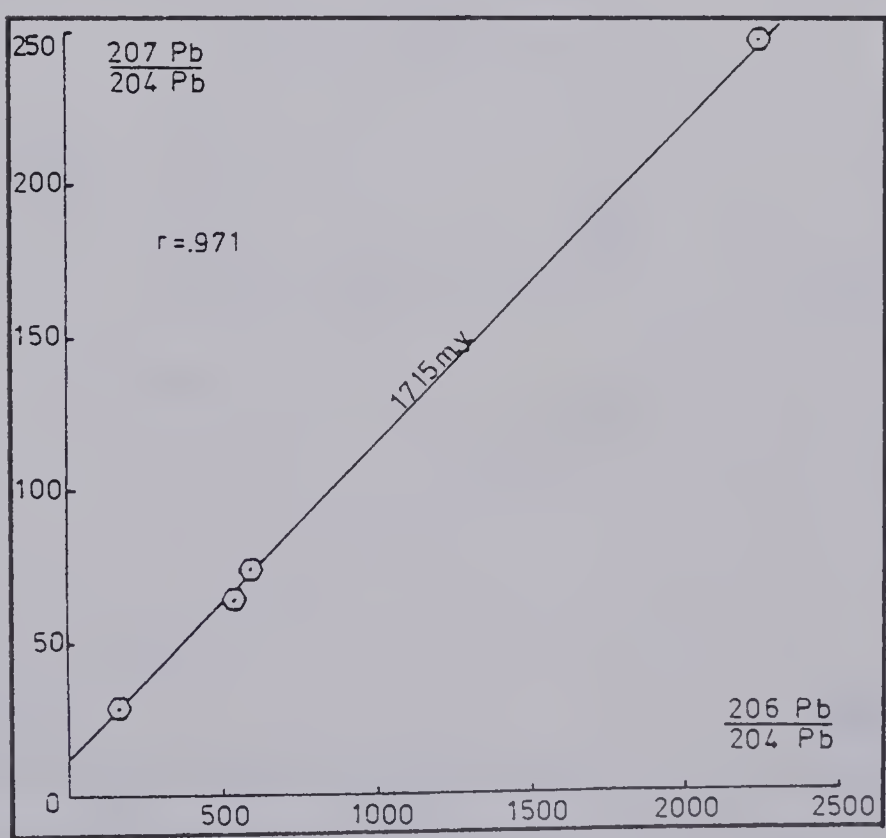


Figure 17. Toopon Lake Samples, 206 Pb/204 Pb. versus 207 Pb/204 Pb Plot.

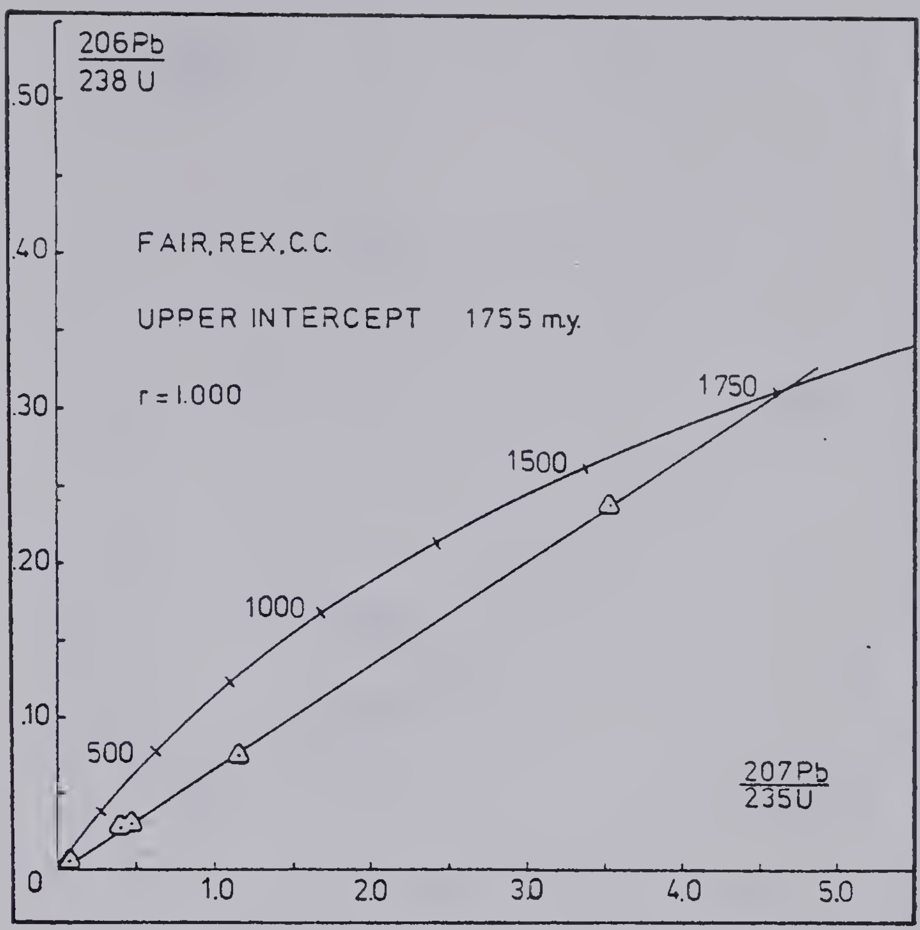


Figure 18. Fair, Rex and C.C. Claims Samples, U-Pb Concordia Plot.

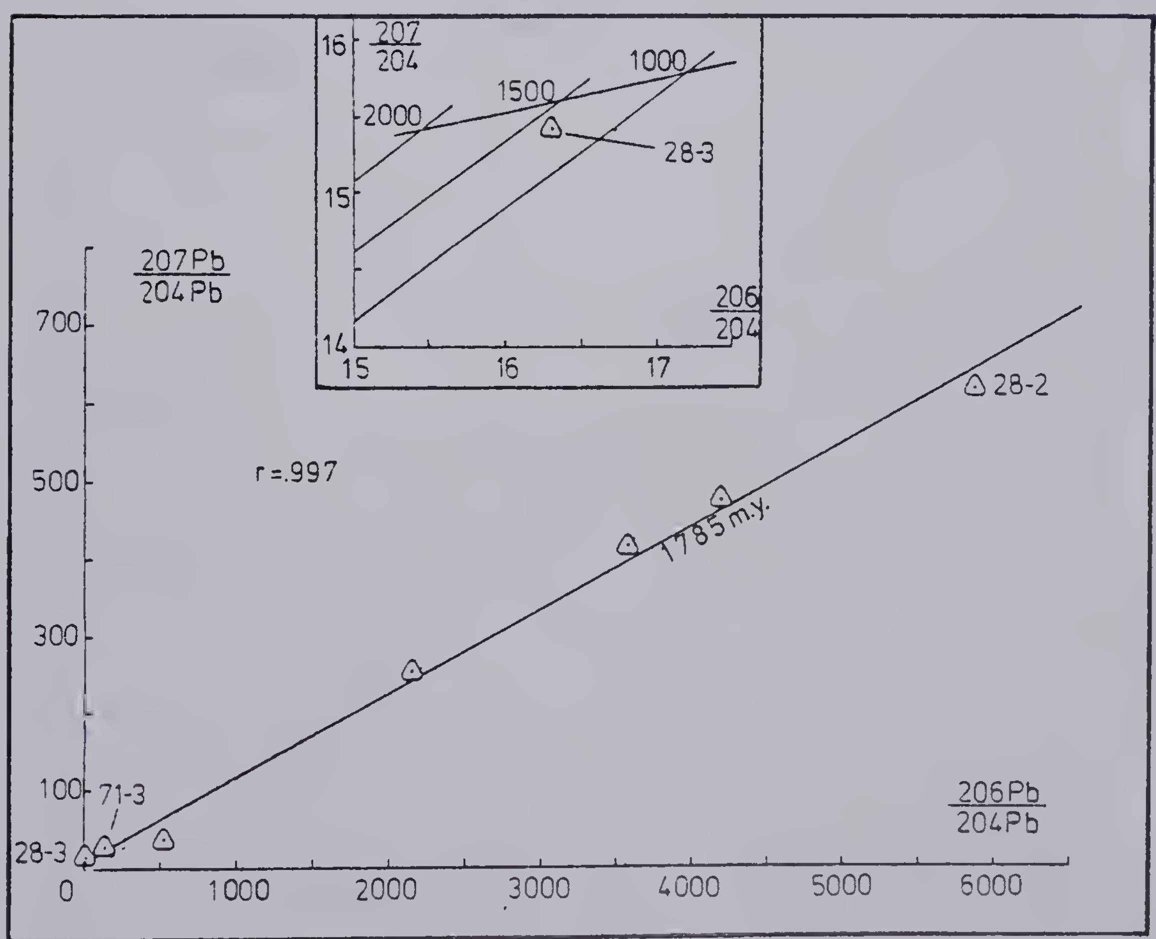


Figure 19. Fair, Rex and C.C. Claims Samples, 206 Pb/ 204 Pb versus 207 Pb/204 Pb Plot.

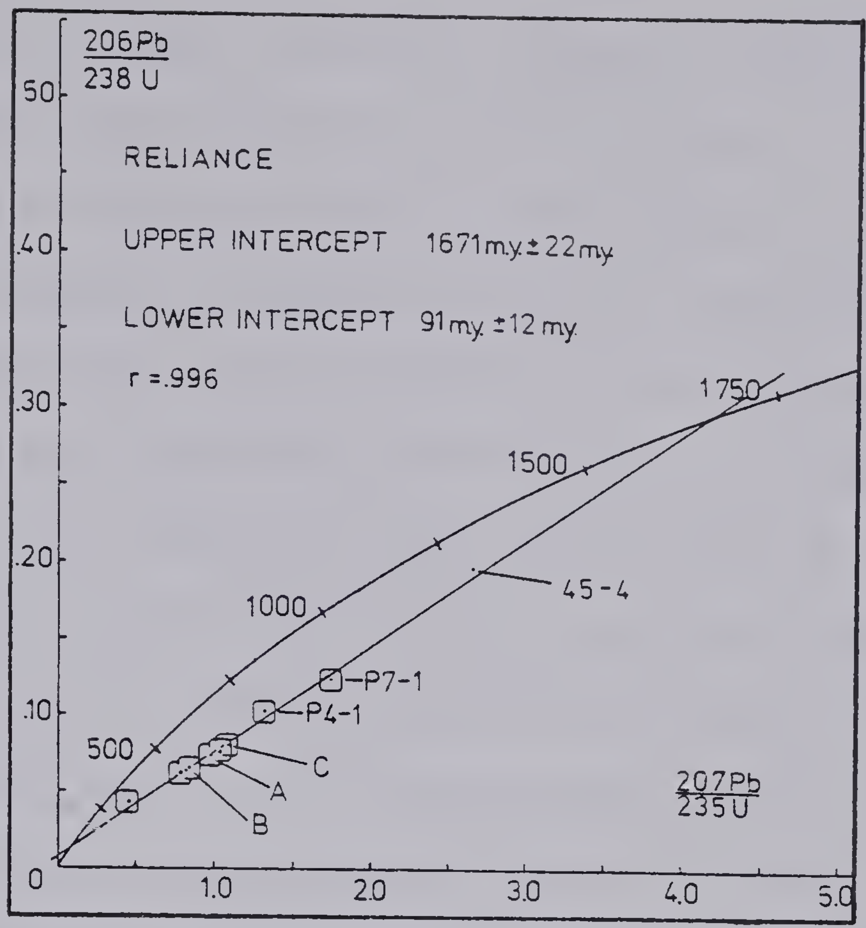


Figure 20. Reliance and MDM and DM Claims Samples, U-Pb Concordia Plot.

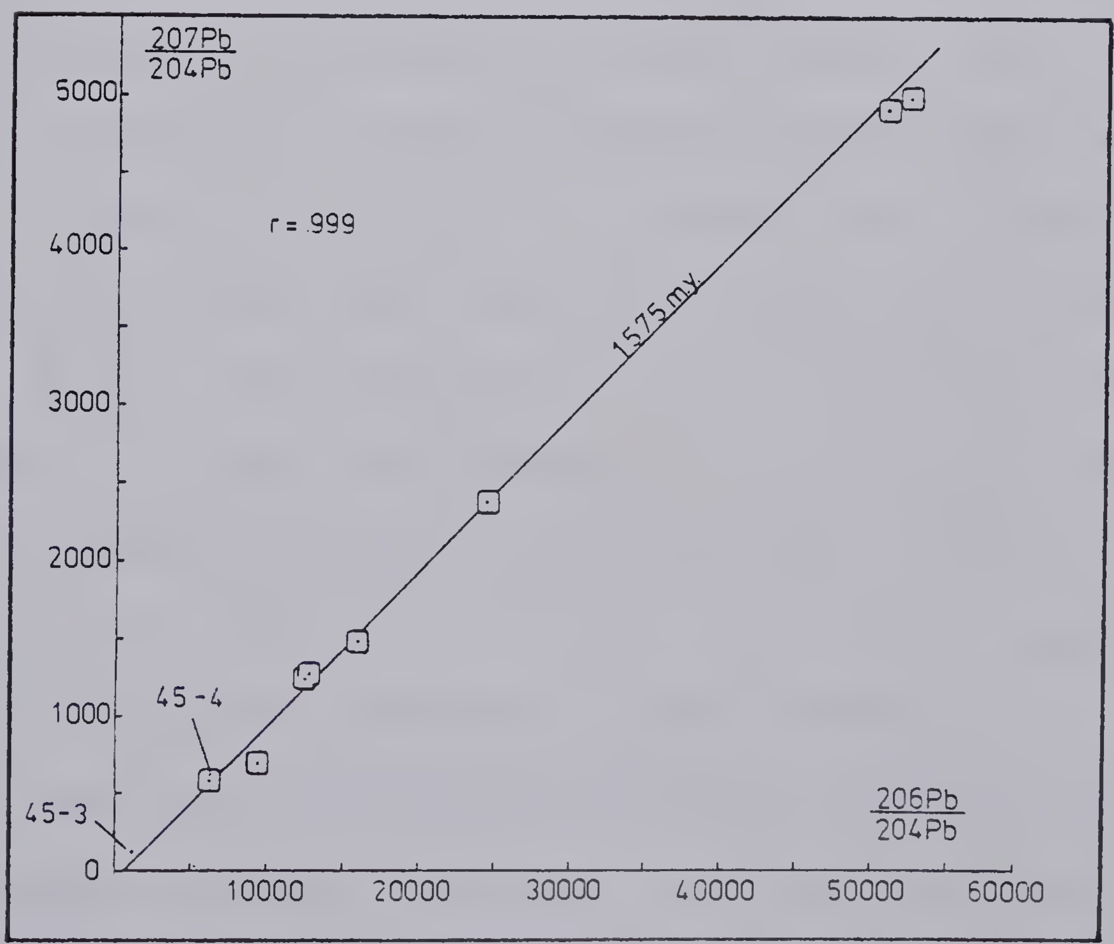


Figure 21. Reliance and MDM and DM Claims Samples, 206 Pb/204 Pb versus 207 Pb/204 Pb Plot.

moment coefficient of linear correlation (r) which is equal to the covariance (x,y) divided by the square root of the variance of x times the variance of y, this correlation method is described by Till (1974).

Most of the samples are moderately to highly discordant where the 206 Pb/238 U, 207 Pb/235 U and 207 Pb/206 Pb relative ages exhibit the classic Pb loss-U gain relationship (206 Pb/238 U age is less than the 207 Pb/238 U age which is much less than the 207 Pb/206 Pb age, Baadsgaard, 1961). There appears to be only one main phase of uranium mineralization observed in the polished section work (Chapter II).

Pb loss in the samples can be substantiated by Cobb's graphical method (Figure 22) using the 207 Pb/206 Pb and 206 Pb/238 U ratios and by ore petrographic work, as the main discordance mechanism. Polished section work described in Chapter II, shows that galena occurs in fractures or on the edges of uraninite grains or in the coffinite phase or in some cases separate from the uranium mineralization. The lead in this galena is radiogenic in nature, although no galena samples were analyzed. From sample U/Pb ratios, it is evident that radiogenic Pb forms most of the galena present (especially in the clastic hosted deposits). Berman's (1957) work and conclusions coincide with this concept where he concludes that radiogenic Pb is exsolved from uraninite due to its incompatability with the uraninite crystal structure.

Cobb and Kulp's (1961) graphical method shows whether a sample has lost Pb or lost U or lost intermediate daughter products of 238 U decay. This decay scheme (238U) is the most susceptible to daughter migration due to its greater abundance. Figure 22 has an inset which specifies the fields and lines of these losses. The Simpson Islands and Reliance samples have suffered Pb loss, the Fair, C.C., Rex (Caribou intrusion)

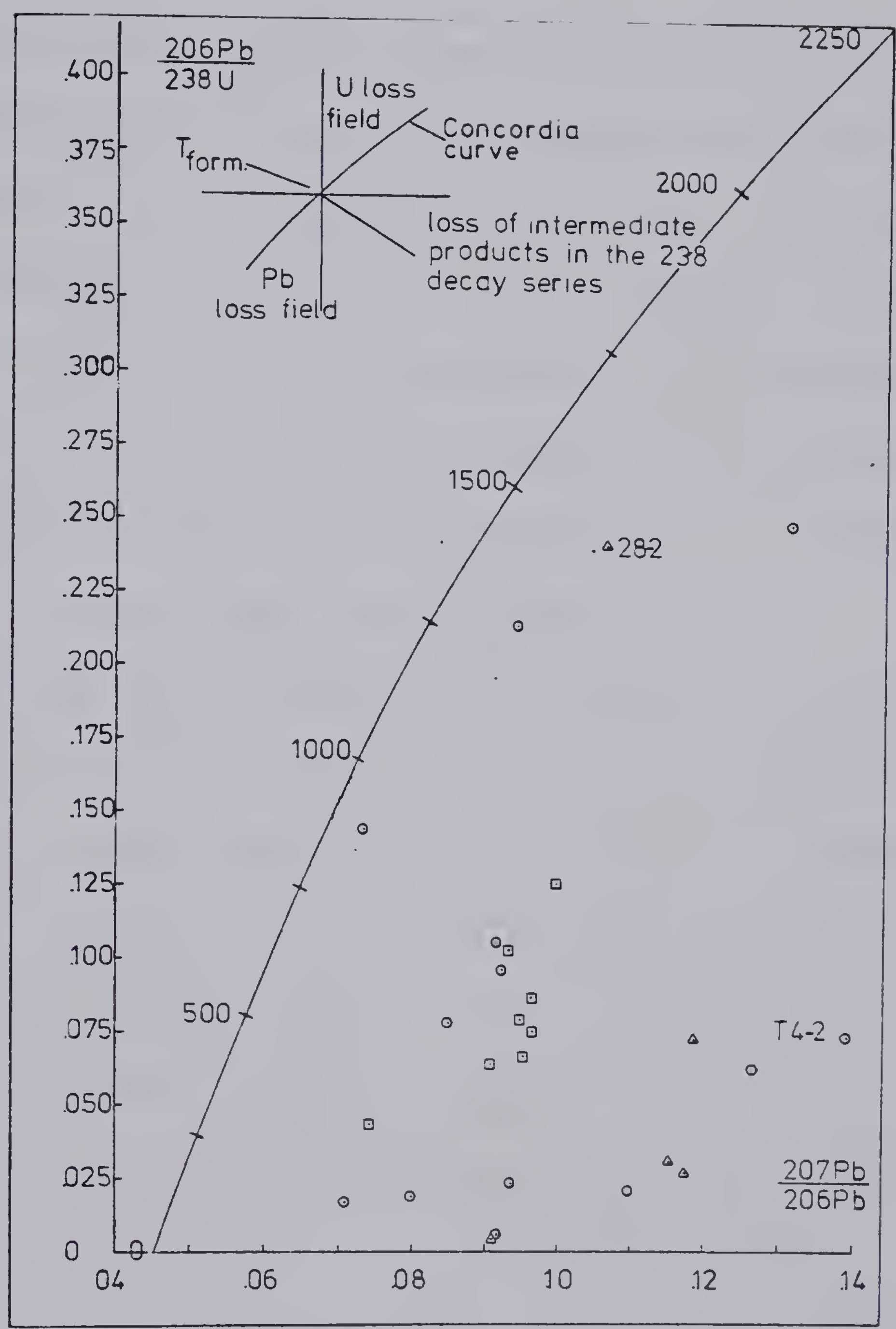


Figure 22. Graphical Presentation to Show Type of Daughter Loss. (Cobb and Kulp, 1961)

samples have suffered both Pb loss and some intermediate daughter loss while Toopon Lake samples have experienced extensive intermediate daughter loss. A pure Pb loss would still allow a good geochronological estimation of the age of emplacement or update of the ore by means of an U-Pb isochron plot.

The Simpson Islands samples (Figure 14) show a good but moderately discordant discordia line giving an intersection age of 1510 m.y.. The Pb-Pb plot (Figure 15) has a slope age of 1405 m.y.. Two samples were discarded to construct the "best fit" lines in Figures 14 and 15, samples T10-1 and T4-2. Sample T4-2 was not used due to its' anomalous trace element geochemistry (Chapter II) while sample T10-1 was not used since the sample location is 4800m to the west of trenches 4, 6 and 9, where isotopic conditions would have been different.

The Toopon Lake samples concordia plot (Figure 16) gives an older possible date than the Pb-Pb plot (Figure 17). The older age is dependant upon ignoring a badly discrepant point which is not discrepant on the Pb-Pb plot. As already noted the Toopon samples have suffered significant daughter loss, making geochronological interpretations difficult.

The Caribou Intrusion samples of the Fair, C. C. and Rex claims show good correlation between the Pb-Pb and U-Pb plots (Figure 18 and 19). These ages (1755 and 1785 m.y.) correspond favourably with Rb-Sr dating of the host quartz monzonite which will be discussed in the following chapter in greater detail. The samples of the Fair, C.C. and Rex claims were grouped together as a result of the similarity in host rocks, and assuming that all the laccoliths of the Caribou intrusions were emplaced contemporaneously (Hoffman, 1977).

The Reliance samples (Figure 20) show a good but very discordant

discordia line giving an intersection age of 1671 m.y.. The Pb-Pb plot (Figure 21) shows a good correlation with a slope date of 1575 m.y.. The Union Island (MDM and DM claims) samples were graphed on the Reliance plots (Figures 20 and 21) since the mode of emplacement of the two deposits is similar. The Union Island samples cannot be used to interpret an age of emplacement for this deposit since the sample size is too small. A close comparison of the Union Island's and Reliance's 207 Pb/206 Pb slopes (Table VII) suggests that both deposits may belong to the same mineralization event.

Most of the samples analyzed are moderately to highly discordant, it was possible to construct "best fit" discordia lines giving minimum concordia intersection ages.

4. Discussion of Discordance in the East Arm Samples

The Reliance, Simpson Islands, and Caribou Intrusions (Rex, Fair and C.C. Claims) samples have suffered Pb loss as the main mechanism of discordance. The Toopon Lake samples have undergone both extensive Pb and intermediate daughter loss, and thus are uninterpretable.

Sampling (handpicking versus leaching) did not ensure more concordant samples as shown in the Reliance examples (Figure 20) where leached samples (P7 and P4-1) are more concordant than the handpicked samples (Rel. A, B and C). Radiogenic Pb is very mobile, an example of this is the Union Island deposit. Sample 45-4 is ore material and sample 45-3 is of the impermeable host carbonate, 45-3 is enriched in radiogenic lead (Table VII). This lead mobility is also shown by Ludwig (1978) in the Shirley Basin uranium deposits where there is extensive radiogenic Pb mobilization.

The Simpson Islands and Reliance samples systematics represents episodic Pb loss (Figures 14 and 20) in recent times (21 m.y. and 90 m.y. respectively), possibly due to groundwater or weathering processes while the Caribou Intrusions samples have lost radiogenic Pb in very recent times (Figure 18). The Pb/Pb slope and U/Pb concordia intersection ages for both the Simpson Islands and Reliance samples do not agree, while the Caribou Intrusions Pb/Pb slope and U/Pb concordia intersection agree closely. This is the result of the timing of the episodic Pb loss and the degree of discordance (Russell and Farquhar, 1960).

This work shows that discordant samples are difficult to interpret due to the ignorance of the mechanisms of Pb and intermediate daughter loss from uranium minerals. The ages obtained for the Simpson Islands and Reliance deposits are minimum ages as a result of Pb-loss discordance; while the Caribou Intrusion (Fair, Rex, C. C. claims) age represents the original date of emplacement of the ore.

5. Comparative Geochronology

The relation between the U-Pb dates of the analyzed deposits and the regional geology is summarized on Table IX and Figure 2. One may observe that the data on Table IX are erratic and do not show a succession from older to younger as would be expected in a sedimentary-volcanic pile.

The Caribou Intrusion's deposits (Fair, C. C., Rex) concordia intersection age of 1755 m.y. agrees with Rb-Sr whole rock dates of the host quartz monzonites (Table IX). This date substantiates Badham's (1977) conclusions that the mineralization hosted by the Caribou Intrusions is a late phase differentiate since the date of intrusion and mineralization coincide. The Fair, C.C., and Rex deposit's age corresponds with the

Table IX. Age Relations in the East Arm

GROUP		MAGMATISM	TECTONICS	AGE DETERMINATIONS (in millions of years)
ET-THEN		diabase dykes (Mackenzie swarm)	strike-slip faulting	1315 K-Ar[1]
UNCONFORMITY				
CARIBOU INTRUSIONS*		diorite-monzonite laccoliths	folding	1705±52, 1758±60, 1759±30, 1811±81, Rb-Sr[2] ** Fair, Rex, C.C. 1755, U-Pb
			movement of nappes	
GREAT SLAVE SUPERGROUP	CHRISTIE BAY	basalt		1810±10, Rb-Sr[3]
	STARK MEGABRECCIA	minor basalt		
	PETHEI			
	KAHOCHELLA	basalt & rhyolite (Seton volcanics)		1832±10, Rb-Sr[4] 1805±15, Rb-Sr[2]
	SOSAN*	basalt & felsic porphory	block faulting	** Simpson Islands 1510±9, U-Pb ** Reliance 1671±22, U-Pb
UNCONFORMITY				
UNION ISLAND*		gabbro intrusions		2371±60, 1882±10, Rb-Sr[2]
UNCONFORMITY				
		diabase dyke swarm		
		biotite-bearing diorite dyke		2200 K-Ar[5], 2170 K-Ar[6], 2057±56 K-Ar[7]
		adamellite stocks	mylonitization metamorphism	
WILSON ISLAND		basalt & rhyolite		1855±21, Rb-Sr[2]
UNCONFORMITY				
ARCHEAN BASEMENT				2370 to 2575 K-Ar[1]

1 Stockwell(1964)
2 Wanless(pers.com. to G.Cumming)
3 S.Goff(pers.com.)
4 Baadsgaard, Morton & Olade(1973)
5 Burwash & Baadsgaard(1962)
6 Leech et al(1963)
7 Davidson(1978)
* host to uranium mineralization
** this study

published dates of uranium mineralization of the Beaverlodge area of Saskatchewan where the age of the first epigenetic mineralization is 1780 ± 20 m.y. (Koppel, 1968). The granodiorites, volcanics and sediments which are hosts to the Great Bear Lake Co-Ni-As-Ag-U veins are dated at approximately 1770 m.y. (the Echo Bay volcanics Rb-Sr date 1770 ± 30 m.y., see Rich, 1977). These veins are simiiar in composition to those of the Fair and C. C. veins but the accepted date of the Great Bear Lake mineralization is 1445 ± 20 m.y..

The Reliance (and possibly the MDM and DM) U-Pb date represents either the primary uranium mineralization event or an update. The Simpson Islands U-Pb date of 1510 m.y. is thought to represent an updating due to burial metamorphism when the host rock was overlain by the thickest amount of sediments of the Great Slave Supergroup. There are no comparable published dates similar to the dates of the Simpson Islands and Reliance mineralization.

SUMMARY

The mineralogy and trace element content of the uranium mineral occurrences show considerable variation between each deposit. This variation is the result of differences in time of formation, source and host rock composition and mode of emplacement. The Reliance, MDM and DM, and Caribou Intrusion (Rex, Fair and C.C.) deposits were apparently formed by hydrothermal fluids; however, they are hosted by different lithologies (ie. sandstones at Reliance, carbonates at the MDM and DM claims and quartz monzonites at the Caribou Intrusions deposits). The Simpson Islands and Toopon Lake deposits are hosted by granule-stones and orthoquartzites respectively. These deposits were formed at low temperatures but their mode of emplacement differs where the Toopon Lake uranium mineralization is closely associated with alteration of ilmenite and carbonaceous material while the Simpson Island's mineralization is associated with pyrite. Interestingly, most of the deposits have the same trace elements or minerals present but in different quantities. The reasons for this variation are the differences listed above.

The Simpson Island deposits represent what may be called a remobilized placer deposit. In many respects these deposits are similar to the classic examples of placer deposits at Blind River - Elliot Lake, Ontario and the Dominion Reef mine in South Africa. The common host of the mineralization is a quartz pebble granulestone or conglomerate derived from ancient braided streams. The overall setting of the Simpson Island mineralization is similar to the Blind River - Elliot Lake

deposits where both reduced and oxidized iron mineralization are present, where the higher grades of uranium are associated with the reduced iron mineralization (pyrite). Mineralogically they are similar, since both uraninite and pyrite are dominant constituents with trace amounts of gold. The Simpson Island deposits are thought to be remobilized since these deposits have undergone tectonic and regional metamorphic events which must have affected the chemical and U-Pb isotope systems of the occurrences. The host has been interpreted to have no porosity and permeability thus limiting the mobility of the uranium mineralization. The mineralization exhibits a very weak hydrothermal replacement of the matrix, in comparison to the Reliance deposits (Plate II, No. 4) where extreme replacement occurs. It has been mentioned that sample T4-2 is anomalous in chemical and isotope composition. The chemical composition of this sample is similar to the Dominion Reef and Blind River - Elliot Lake deposits. This sample (T4-2) may represent a relict phase of the original Simpson Island occurrences (a placer uranium deposit).

The Toopon Lake mineralization appears to be similar to the U.S. type of epigenetic sandstone deposits. The host rock of the Toopon deposits is a fine-grained orthoquartzite, which was porous after deposition. The uranium mineralization was then precipitated at deposition sites of ilmenite and carbonaceous material (hydrocarbons ?). The porosity was then closed by quartz overgrowths. The mineralogy, chemistry, and mode of deposition are all similar to the U.S. roll-type epigenetic deposits.

The Reliance deposits are a hydrothermal type of uranium deposit with the mineralization totally replacing the matrix and altering the

feldspar grains; leaving only the resistant quartz grains of the host intact. The mineralogy and chemistry of this deposit is similar to the hydrothermal epigenetic type of deposit in the Beaverlodge area of Saskatchewan (Rich et al, 1977; Ruzicka, 1971; Robinson, 1955) where there is a hematite-pyrite-uranium-cobalt-nickel-arsenide assemblage.

The Fair, C. C. and Rex occurrences are hosted by the quartz monzonites of the Caribou Intrusions. These deposits are derivatives of late phase differentiates of the host intrusion (Badham, 1977). The Co-Ni-As-Ag-U veins are similar to Great Bear Lake examples (Rich et al, 1977; Badham, 1977) in mineral assemblage and mode of occurrence. The agreement of dates obtained for both host and mineralization concurs with Badham's (1977) hypothesis that the ore is a derivative of the late phase differentiate of the host.

The majority of U-Pb values for the samples were moderately to extremely discordant. This discordancy is the result of loss of radiogenic lead and/or intermediate daughters of the uranium decay scheme. Cobb and Kulp's (1961) diagram (Figure 22) can indicate whether the samples have lost radiogenic Pb or intermediate daughters from the 238 U decay scheme. Accordingly the Simpson Islands and Reliance samples have lost radiogenic Pb, the Fair, C.C. and Rex samples have lost radiogenic Pb and minor amounts of intermediate daughters while the Toopon Lake samples have suffered intermediate daughter loss which has made reliable geochronology improbable.

The radiogenic lead loss from the Simpson Islands, Reliance and Caribou Intrusion's samples is the result of radiogenic lead migrating from the uranium mineral lattice to form galena or having left the isotope system completely. Whole rock leaches of the ore and host and

handpicked uranium mineral samples show lead loss indicating the analyzed mineral deposits were in open systems in which outside processes (ie. groundwater flow or surficial weathering) carried radiogenic lead away from the ore bodies. The radiogenic lead migration phenomenon has been well documented by K. Ludwig (1978) in Tertiary uranium deposits in the Shirley Basin of Wyoming. These very young uranium ores have undergone radiogenic lead migration to other parts of the ore body or out of the isotope system.

In open system isotope dating it was important to determine what type of daughter loss is occurring. As previously mentioned the Simpson Islands, Reliance and Caribou intrusions deposits have mainly host radiogenic lead while the Toopon Lake has lost intermediate daughters and radiogenic Pb. It was assumed that those samples which mainly lost radiogenic lead would give valid dates.

The U-Pb apparent ages of the Simpson Islands and Reliance deposits are younger than the Great Slave Supergroup sedimentary-volcanic pile which is older than 1755 m.y. (Table IX). The date of the Simpson Islands uranium mineralization (1510 ± 9 m.y.) is an update due to burial metamorphism, this deposit was formed during deposition of the host granule-stone of the Hornby Channel formation. The apparent age of the Reliance uranium occurrence (1671 ± 22 m.y.) represents either a date of emplacement or a possible update. The Fair, Rex and C.C. mineralization of the Caribou Intrusions U-Pb apparent age (1755 m.y.) compares favourably with Rb-Sr dates of the host (see Table IX). Unfortunately a reliable age could not be obtained for the Toopon Lake mineralization as a result of intermediate daughter loss altering the U-Pb systematics of the uranium mineralization.

In conclusion, with the use of trace element geochemistry, sedimentology, petrographic and paragenetic relations of the ore and field relations of uranium mineralization it was possible to obtain reasonable apparent ages and determine what types of uranium mineralization are present in the East Arm of Great Slave Lake.

BIBLIOGRAPHY

Abbey, S., Gillieson, A. H. and Perrault, G., (1975), SY-2, Sy-3, and MRG-1, A Report on the Collaborative Analysis of Three Canadian Rock Samples for Use as Certified Reference Materials, Can. Certified Ref., Materials Proj., MRP/MSL 75-132 (TR).

Baadsgaard, H., Morton, R. D. and Olade, M.A.D., (1973), Rb-Sr Isotopic Age for the Pre Cambrian Lavas of the Seton Formation, East Arm of Great Slave Lake, Northwest Territories, Can. J. Earth Sci., 10, 1579-1582.

Baadsgaard, H., (1965), Geochronology, Medd. Dansk Geol. Forening., 16, 2-48.

Badham, J. P. N., (1977), Magnetite-Apatite-Amphibole, Uranium and Silver Arsenide Mineralization in Lower Proterozoic Alkaline Rocks, East Arm of Great Slave Lake, Canada, preprint for Econ. Geol.

Badham, J. P. N. and Morton, R. D., (1976), Magnetite-Apatite Intrusions and Calc-Alkaline Magmatism, Camsell River, N.W.T., Can. J. Earth Sci., 13, 348-354.

Bucknell, W. R., (1975), Reliance Option, Vestor Exploration Ltd., Charlton Bay Area, N.W.T., Rio Algom Internal Rep. 75-K-11, 18 pg.

Burwash, R. A. and Baadsgaard, H., (1962), Yellowknife-Nanacho Age and Structural Relations, Royal Soc. Can. Spec. Publ. No. 4, 22-30.

Cobb, J. C. and Kulp, J. L., (1961), Isotopic Geochemistry of Uranium and Lead in the Swedish Kolm and Its' Associated Shale, Geochim. Cosmochim. Acta , 24, 226-249.

Davidson, A., (1978), The Blachford Lake Intrusive Suite, an Aphebian Alkaline Plutonic Complex in the Slave Province, Northwest Territories, Geol. Surv. Can. Pap. 78-1A, 119-127.

Doe, B.R., (1970), Lead Isotopes, Springer-Verlag, 137 pg.

Dooley, J. R., Harshman, E. N. and Rosholt, J. N., (1974), Uranium-Lead Ages of the Uranium Deposits of the Gas Hills and Shirley Basin, Wyoming., Econ. Geol., 69, 527-31.

Finch, W. I., (1967), Geology of Epigenetic Uranium Deposits in Sandstone in the United States, U. S. Geol. Surv. Prof. Pap. 538, 121 pg.

Flanagan, F. J., (1973), Reference Samples for the Earth Sciences, Geochim. Cosmochim.Acta, 38, 1731 - 44.

Folk, R. L., (1968), The Petrology of Sedimentary Rocks, Austin, The University of Texas, 153 pg.

Gableman, J. W., (1977), Migration of Uranium and Thorium, Am. Assoc. Petrol. Geol. Studies in Geology, No. 3, 168 pg.

Gandhi, S. S., (1978), Geological Observations and Exploration Guides to Uranium in the Bear and Slave Structural Provinces and the Nonacho Basin, District of Mackenzie, Geol. Surv. Can. Pap. 78-1A, 141-149.

Hiemstra, S. A., (1968), The Mineralogy and Petrology of the Uraniferous Conglomerate of Dominion Reefs Mines, Klerkdorp Area, Trans. Geol. Soc. S. Africa, 71, 1-66.

Hiemstra, S. A., (1968), The Geochemistry of the Uraniferous Conglomerates of the Dominion Reefs Mines, Klerkdorp Area, Trans. Geol. Soc. S. Africa, 71, 67-100.

Hills, J. H. and Richards, J. R., (1976), Pitchblende and Galena Ages in the Alligator Rivers Region, Northern Territory, Australia, Mineralium Deposita, 11, 133-154.

Hoffman, P. F., (1968), Stratigraphy of the Lower Proterozoic and the Great Slave Supergroup, East Arm of Great Slave Lake, District of Mackenzie, Geol. Surv. Can. Pap. 68-42, 93 pg.

Hoffman, P. F., (1969), Proterozoic Paleocurrents and Depositional History of the East Arm Fold Belt, Great Slave Lake, N.W.T., Can. J. Earth Sci., 6, 441-462.

Hoffman, P. F., Fraser, J. A., McGlynn, J. C., (1970), The Coronation Syncline of Aphebian Age, District of Mackenzie, Geol. Surv. Can. Pap. 70-40, 201-212.

Hoffman, P. F., (1973), Aphebian Supracrustal Rocks of the Athapuscow Aulacogen, East Arm of Great Slave Lake, District of Mackenzie, Geol. Surv. Can. Pap. 73-1A, 151-156.

Hoffman, P. F., Dewey, J. F. and Burke, K., (1974), Aulacogens and their Genetic Relation to Geosynclines with a Proterozoic example from Great Slave Lake, Canada, Soc. Econ. Paleon. and Minr. Spec. Publ. 19, 38-55.

Hoffman, P. F., Bell, P. R., Hildebrand and Thorstad, L., (1977), Geology of the Athapuscow Aulacogen, East Arm of Great Slave Lake, District of Mackenzie, Geol. Surv. Can. Pap. 77-1A, 117-129.

Jaffey, A. H., Flynn, K. F., Glendenin, L. E., Bentley, W.C., and Essling, A. M., (1971), Precision Measurement of Half Lives and Specific Activities of 235 U and 238 U, Physical Review C, 4, 1889-1906.

Koeppel, V., (1968), Age and History of the Uranium Mineralization of the Beaverlodge Area, Saskatchewan, Geol. Surv. Can. Pap., 67-31, 111 pg.

Krogh, T.E., (1973), A Low Contamination Method for Hydrcthermal Decomposition of Zircon and Extraction of U and Pb for Isotopic Age Determinations, Geochim. Cosmochim. Acta, 37, 485-494.

Lang, A. H., Griffith, J. W. and Steacy, H. R., (1962), Canadian Deposits of Uranium and Thorium, Geol. Surv. Can. Econ. Geol. Series No. 16, 2nd Edition, 324 pg.

Leech, G. B., Lowdon, J. A., Stockwell, C. H. and Wanless, R. K., (1963), Age determinations and Geologic Studies, Geol. Surv. Can. Pap 63-17, 140 pg.

Louw, J. D., (1954), Geological Age Determination on Witswaterand Uraninites using the Lead Isotope Method, Geol. Soc. S. Afr. Trans., 57, 209-230.

Ludwig, K. R., (1978), Uranium Daughter and U/Pb Isotope Apparent Ages of Uranium Ores, Shirley Basin, Wyoming, Econ. Geol., 73, 29-49.

McGlynn, J. C., (1971), Metallic Mineral Industry, District of Mackenzie, Northwest Territories, Geol. Surv. Can. Pap. 70-17, 194 pg.

Miesch, A. T., (1963), Distribution of Elements in Colorado Plauteau Uranium Deposits - A Preliminary Report, U. S. Geol. Bull. 1147-E, 57 pg.

Morton, R. D., (1974), Sandstone Type Uranium Types in the Proterozoic Strata of Northwestern Canada, from Formation of Uranium Ore Deposits, International Atomic Energy Agency, Athens, 255-271.

Olade, M. A. D. and Morton, R. D., (1972), Observations on the Proterozoic Seton Formation, East Arm of Great Slave Lake, Northwest Territories, Can. J. Earth Sci., 9, 1110-23.

Oladegbule, M. A., (1971), Geological Report on the Toopon Lake Property of Vestor Exploration Ltd. in the East Arm of Great Slave Lake, N.W.T., Vestor Exploration Ltd., Internal Co. Rep., 66 pg.

Oladegbule, M. A., (1971), Geological Report on the Reliance Claims, MER, MAID, MAU, HEB and ZEB in the East Arm of Great Slave Lake, N.W.T., Vestor Exploration Ltd., Internal Co. Rep., 28 pg.

Ramdohr, P., (1969), The Ore Minerals and Their Intergrowths, Pergamon Press, 1174 pg.

Reinhardt, E. W., (1972), Occurrences of Exotic Breccias in the Pettitot Islands (85H/10) and Wilson Island (85H/15) map areas, East Arm of Great Slave Lake, District of Mackenzie, Geol. Surv. Can. Pap. 72-25, 43 pg.

Reinhardt, E. W., (1969), Geology of the Pre E Rocks of the Thubun Lakes Area in Relationship to the McDonald Fault System, Geol. Surv. Can. Pap. 69-21, 29 pg.

Reynolds, R. L., Goldhaber, M. B. and Grauch, R. I., (1977), Uranium Associated with Iron-Titanium Oxide Minerals and Their Alteration Products in a South Texas Roll Type Deposit, U. S. Geol. Surv. Circ. 752, 37-39.

Rich, R. A., Holland, H. D. and Petersen U., (1977), Hydrothermal Uranium Deposits, Elsevier Scientific Publ. Co., 264 pg.

Roscoe, S. M., (1968), Huronian Rocks and Uraniferous Conglomerates, Geol. Surv. Can. Pap. 68-40, 205 pg.

Robinson, S.C., (1955), Mineralogy of Uranium Deposits, Goldfields, Saskatchewan, Geol. Surv. Can. Bull., 31, 128 pg.

Russell, R. D. and Farquhar, R. M., (1960), Lead Isotopes in Geology, Interscience Publishers, 243 pg.

Ruzicka, V., (1970), Geological Comparison between East European and Canadian Uranium Deposits, Geol. Surv. Pap. 70-48, 196 pg.

Stieff, L. R., Stern, T. W. and Eicher, R. N., (1963), Algebraic and Graphic Methods for Evaluating Discordant Lead Isotope Ages, U. S. Geol. Surv. Pap. 414-E, E1-E27.

Stockwell, C. H., (1964), Age Determinations and Geological Studies, Geol. Surv. Can. Pap. 64-17, pt II, 12-14.

Tatsumoto, M., (1970), U-Th-Pb Age of Apollo 12 Rock 12013, Earth Plan. Sci. Letters, 9, 193-200.

Thorpe, R. I., (1972), Mineral Exploration and Mining Activities, Mainland Northwest Territories, 1966 - 1968, Geol. Surv. Can. Pap. 70-70, 204 pg.

Tilton, G. R., (1960), Volume Diffusion as a Mechanism for Discordant Lead Ages, J. Geophys. Res., 65, 2933-2945.

Till, R., (1974), Statistical Methods for the Earth Scientist, J. Wiley and Sons, 154 pg.

Vos, R. G., (1975), An Alluvial Plain and Lacustrine Model for the Pre-Cambrian Witswaterand Deposits of South Africa, J. Sed. Petr., 45, 480 - 493.

Walker, R. G., (1976), Facies Model, 3. Sandy Fluvial Systems, Geoscience Canada, 3, 101-109.

Walker, R. R., (1977), The Geology and Uranium Deposits of Proterozoic Rocks, Simpson Islands, Northwest Territories, M. Sc. Thesis,

University of Alberta, 193 pg.

Walker, R. R., (1971), Detailed Geological Report on the Simpson Islands Claims of Vestor Exploration Ltd. in the East Arm of Great Slave Lake, N.W.T., Pt. I and II, Vestor Exploration Ltd., Internal Co. Rep., 58 pg. and appendixes.

Wasserburg, G. J., (1963), Diffusion Processes in Pb-U Systems, J. Geo. Phys. Res., 68, 4823-4846.

Wetherill, G. W., (1956), Discordant Uranium - Lead Ages I, Trans. Am. Geophys. Union, 37, 320-326.

Wetherill, G. W. (1963), Discordant Uranium - Lead Ages II, Geophys. Res., 68, 2957-2965.